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REPRESENTATIONAL INQUIRY IN SCIENCE LEARNING GAMES

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ENGLISH SUMMARY

This thesis concerns the enactment of competences and learning in the science learning game *Homicide* played in schools. It explores the new practice of profession simulation in games by applying a theoretical approach inspired by science and technology studies (STS). The enacted practices in the game *Homicide* are investigated through empirical studies done on four school classes playing the game. The focus of the thesis was based on the following research questions:

- What practices, competences and tools are enacted when the game *Homicide* is played in schools?
- How are competences, learning and tools enacted in networks of related entities in the school settings the game is played in?

The investigation of these questions is divided into three parts. Part 1 concerns the development and study of the empirical research field which encompasses the game *Homicide* played in four seventh to ninth grade Danish lower and upper secondary school classes. *Homicide* is a forensic investigation game where students solve murder mysteries in the space of one week. The game is designed to support work with professional scientific inquiry processes and to meet the seventh to tenth grade curriculum objectives for science and Danish education. Part I describes how design-based research (DBR) was used to develop and study the game *Homicide* in iterative cycles of problem definition, design, intervention and analysis. The field work was thus carried out in cycles of implementation of the design experiments in the different classes. I describe how an observational focus was established on the representations students constructed and used in their investigation processes. The design experiments in the different classes thus became focused on doing interventions to investigate different aspects of the representational practices. Interventions was thus done to investigate aspects such as meta-reflective representational practices, and to understand factors influential for the initial construction of representations in the three classes.

The analytical parts of the thesis, Part II and III, is an exploratory study of the enactment of representational practices, competences and learning using different theoretical approaches. Part II focuses mainly on understanding the practices and competences students engaged in the construction and use of representations in inquiry processes. The focus on student agency changes partly in Part III, where I attempt to understand the networks of related entities that representations and representational practices and competences are enacted in.
In Part II, Chapter 5, I begin by addressing the representational practices observed in the first class I did observations in. I investigate student practices in relation to the construction and use of representations in class presentations by applying STS concepts of inscriptional scientific practice. The representational practices observed in the first class are shown to be parallel in several ways to the epistemology of scientific inscriptional practice as defined in STS. How the student practices differ from the scientific inscriptional practices was, however, also shown, including the inquiry process-orientated use of representations. At the end of this chapter, I use the concept of meta-representational competences to initiate a discussion of what competences students engage in this work. This discussion continues in Chapter 6, where I focus on the inquiry process representations are used for. I use definitions of inquiry skills as theory-evidence coordination to analyze the students’ use of representations in inquiry processes. I show that students use representations in the construction of hypotheses for clarifying which elements of their hypotheses are based on theories (understood as the student’s mental representation of what happened in the case) and which elements are based on evidence (understood as sources of knowing). Representations are also used for incorporating new evidence, and treating it independently of, and coordinating it with, theory.

At the end of Part II, I draw on the insights from Chapters 5 and 6 in developing the term *Representational Inquiry Competence* to define the competences students enact in the game *Homicide*. Representational inquiry competence is defined as: The ability to construct, productively use, transform and critique visual representations as an integrated part of doing inquiry into defining an unknown phenomenon. It includes the ability to visually represent the phenomena subjected to inquiry and the inquiry strategies that go into investigating the phenomenon and the ability to construct and use representations for investigating, coordinating and relating evidence, hypotheses, and theory.

Part III focuses on understanding representational inquiry and inquiry representations as enacted in networks of related entities such as students, boards, teachers and game interfaces. The inspiration for this methodological approach is based on theories of distributed cognition and actor-network theory (ANT). Chapter 7 studies how inquiry representations take part in the students’ knowledge construction and learning about their case by applying the theoretical approach of distributed cognition. In this chapter it is argued that the inquiry representations can be understood as mediating artifacts that connect students and the task of solving the case. Inquiry representations mediate this process by bringing the representational states of game elements into coordination. The coordination takes place in a process where the representational states of elements such as characters propagate over various media with the aim of being included in the students’ representations. By comparing processes of inquiry
during the analysis phase in two classes, I show that the different formats of inquiry representations in the two groups act as mediating artifacts in different phases of the inquiry. In this chapter I also show how transformations of representations are an integrated part of the groups’ inquiries. I argue that student learning about their case and knowledge construction take place as a reorganization of representational structures. The inquiry representations, however also differed in central ways from the formalized mediating artifacts defined in distributed cognition. By playing Homicide, students invent and construct their own procedures and formats of mediating artifacts while re-representing the data.

Transformations of formats as a central element of representational inquiry is further analyzed in Chapter 8 in terms of the ANT concept of fluidity. In this chapter, I seek to understand the mutability of representations in phases of inquiry in and across different classes. The conclusion reached in this investigation is that inquiry representations act as a shape-changing actor with different identities enacted in networks of fluent student relations and practices. In Chapter 9 I attempt to understand what networks of entities in the classes playing the game Homicide enact the construction of inquiry representations and their various identities. I use the actor-network concept of multiple enactments of objects and argue that representations are enacted in networks of patterns of present and absent actors such as boards, police fiction, computers, and teachers. It is argued that these networks bring inquiry representations into presence in a variety of shapes and designs and with different functional foci. It is, however, not only inquiry representations that end up being present in particular networks of actors, but also the competences that go into conducting inquiry by creating representational structures.

In Chapter 10, which contains discussions and conclusions, I discuss the value of representational inquiry competences in the context of science education in schools and in scientific and creative professions. I conclude that the representational inquiry competences are central in science practices, but that we need further studies of the different elements and processes involved in representational inquiry. Examples of future set ups for studying these elements are also provided at the end of Chapter 10. In this chapter I discuss the conclusions made in the various chapters in the thesis in terms of overlapping relations, effects and practices that might exist of the different versions of inquiry representations. An exciting aspect for future studies is to investigate student representational practices in terms of the ANT concept of the forthcoming definition of The Materiality of Learning. The thesis ends with the conclusion that the ANT-inspired methodological approach applied to parts of this thesis can contribute new understandings of what enact competences and learning in games.
DANSK RESUMÉ

Denne afhandling er en undersøgelse af de praksisser, de kompetencer og den læring, der fremkommer i det naturfaglige læringsspil Drabssag Melved (Homicide), spillet i en skolekontekst. Afhandlingen udforsker interaktionen i denne type professionssimulationsspil gennem en teoretisk tilgang inspireret af videnskabs- og teknologistudier (science and technology studies - STS). Praksisser i spillet Drabssag Melved undersøges gennem empiriske studier af fire skoleklassers gennemspilninger af spillet. Afhandlingens fokus er baseret på følgende forskningsspørgsmål:

- Hvilke praksisser, kompetencer og værktøjer fremkommer, når spillet Drabssag Melved spilles i en skolekontekst?
- Hvordan frembringes kompetencer, læring og værktøjer i netværk af forbundne entiteter indenfor de rammer i skolen, hvor spillet spilles?

Undersøgelsen af disse spørgsmål inddeles i tre dele. Del I beskæftiger sig med udviklingen og studiet af det empiriske undersøgelsesfelt, som omfatter spillet Drabssag Melved, der spilles i fire danske syvende til niende klasser. Drabssag Melved er et kriminalteknisk efterforskningsspil, hvor eleverne skal løse en række mordgåder i løbet af en uge. Spillet er udformet til at understøtte arbejdet med professionelle videnskabelige undersøgelsesprocesser og til at opfylde undervisningstrinmål i naturfagene og dansk for folkeskolens syvende til tiende klasser. Del 1 i denne afhandling beskriver, hvordan designbaseret forskning (design-based research - DBR) blev anvendt til at udvikle og studere spillet Drabssag Melved i gentagne cyklusser af problemdefinition, design, intervention og analyse. Det beskrives, hvordan et fokus på elevernes konstruktion og brug af repræsentationer i undersøgelsesprocesser blev etableret igennem cyklusser af implementering af designeksperimenter i de forskellige klasser. Designeksperimenterne i de forskellige klasser blev således fokuseret på at foretage interventioner indenfor de forskellige aspekter af denne repræsentationspraksis. Eksempler på sådanne interventioner var eksperimenter, der havde til formål at undersøge, hvilke elementer der har indflydelse på den indledende konstruktion af repræsentationerne og undersøgelse af elevernes meta-refleksion over repræsentationsformater og strategier.

De analytiske dele af afhandlingen, Del II og III, er en eksplorativ undersøgelse af de repræsentationspraksisser og kompetencer og den læring, der fremkommer i den spil-baserede kontekst. Undersøgelsen trækker på forskellige teoretiske tilgange. Del II fokuserer hovedsageligt på de praksisser og kompetencer, de studerende engagerer i konstruktionen og
brugen af repræsentationer i undersøgelsesprocesser. Fokussen på de studerendes praksisser ændres delvist i Del III, hvor jeg forsøger at forstå de netværk af relatede entiteter, som de studerendes kompetencer og repræsentationer fremkommer i.

I Del II, Kapitel 5, præsenteres repræsentationspraksisser i den første klasse, jeg foretog observationer i. I dette kapitel anvender jeg en teoretisk tilgang baseret på STS-definitioner af videnskabelig inskriptionspraksis i et forsøg på at forstå de studerendes praksisser i relation til konstruktion og brug af repræsentationer i klassepræsentationer. Konklusionen i denne del af undersøgelsen er, at repræsentationspraksisserne i denne første classes epistemologiske tilgang til konstruktion og brug af repræsentationer er parallel med epistemologien for den STS-definerede videnskabelige inskriptionspraksis. Hvordan de studerendes praksisser afviger fra den videnskabelig inskriptionspraksis vises imidlertid også. En central forskel er, at de studerendes repræsentationer udvikles til at understøtte undersøgelsesprocesser snarere end som et redskab til at vinde videnskabelige argumentationer. I slutningen af dette kapitel refererer jeg til begrebet meta-repræsentationskompetencer (meta-representational competences – MRC) for at indlede en diskussion om, hvilke kompetencer de studerende anvender i dette arbejde. Denne diskussion fortsætter i Kapitel 6, hvor jeg fokuserer på, hvordan repræsentationerne bruges i undersøgelsesprocesser gennem en anvendelse af en definition af undersøgelseskompetencer som teori-bevis-koordination. Jeg viser, at de studerende bruger repræsentationer i opbygningen af hypoteser til afklaring af, hvilke elementer i deres hypoteser der er baseret på teorier (forstået som de studerendes mentale repræsentationer af, hvad der er sket i sagen), og hvilke elementer der er baseret på beviser (forstået som kilder til viden). Repræsentationer bruges også til at indarbejde nye beviser og til at behandle dem uafhængigt af, og koordinere dem med, teori. I slutningen af Del II trækker jeg på indsigten fra Kapitel 5 og 6 i udviklingen af termen Repræsentationsundersøgelseskompetence for at definere de kompetencer, de studerende udfører i spillet Drabssag Melved. Repræsentationsundersøgelseskompetence defineres som:

Evnen til at konstruere, produktivt anvende, ændre og kritisere visuelle repræsentationer som en integreret del af udførelsen af undersøgelser for at definere et ukendt fænomen. Det omfatter evnen til visuelt at repræsentere det fænomen, der undersøges, og de undersøgelsesstrategier, der bruges til at undersøge fænomenet, samt evnen til at konstruere og anvende repræsentationer til undersøgelse, koordinering og relatering af beviser, hypoteser og teori.

Del III fokuserer på forståelsen af repræsentationsundersøgelser og undersøgelsesrepræsentation som fremkommet i netværk af relatede enheder, f.eks. studerende, tavler, lærere og spilelementer. Inspirationen til denne metodologiske tilgang

Transformationer af formater som et centralt element i repræsentationsundersøgelsen analyseres yderligere i Kapitel 8 i forbindelse med ANT-konceptet ”fluiditet”. I dette kapitel søger jeg at forstå foranderligheden ved repræsentationer i undersøgelsesfaser i og på tværs af forskellige klasser. Konklusionen i denne undersøgelse er, at undersøgelsesrepræsentationerne fungerer som en foranderlig aktør med forskellige identiteter, der fremkommer i netværk af flydende relationer og praksisser i de enkelte klasser. I Kapitel 9 anvender jeg ANT-begrebet ”mulitple frembringelser af objekter” i et forsøg på at forstå, hvordan konstruktion af forskellige versioner af undersøgelsesrepræsentationer fremkommer i netværk af aktører som f.eks. tavler, politifiktion, computere og lærere. Det argumenteres, at disse netværk frembringer undersøgelsesrepræsentationerne i en række forskellige former og udformninger og med forskelligt funktionelt fokus. Det er imidlertid ikke blot undersøgelsesrepræsentationer, som ender med at være til stede i bestemte netværk af aktører, men også de kompetencer, der anvendes til at udføre undersøgelsen ved at skabe repræsentationsstrukturen. I Kapitel 10, som indeholder diskussioner og konklusioner, diskutere jeg værdien af repræsentationsundersøgelseskompetencer i relation til skolens naturfagsundervisning og i relation til videnskabelige og kreative professioner. Jeg konkluderer, at repræsentationsundersøgelsers kompetencer er centrale i
videnskabspraksisser, men at vi har brug for yderligere studier af de forskellige elementer og processer, der er involveret i repræsentationsundersøgelser. I dette kapitel diskuteres også fokus for fremtidige studier. Jeg diskuterer de konklusioner, der blev foretaget i de forskellige kapitler i afhandlingen i forhold til overlappende relationer, effekter og fremgangsmåder, der måtte findes af de forskellige definitioner af undersøgelsesrepræsentationer. En udvidet forståelse af, hvilken læring der finder sted de beskrevne netværk, vil være et oplagt fokus for fremtidige studier. Afhandlingen slutter med den konklusion, at den ANT-inspirerede metodologiske tilgang, der er anvendt på dele af denne afhandling, kan bidrage med ny forståelse af, hvad der frembringer kompetencer og læring i spil.
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INTRODUCTION

At its outset, this PhD project was formally part of the highly creative game development environment at Learning Lab Denmark, where the game used in the current study, Homicide, was also developed. The development of Homicide was part of the boom that has emerged within the last decade in design and research involving new generations of learning games. In spite of this research focus, relatively little is known about what competences are enacted in science games played in schools and how the games support this enactment and learning. The aim of this thesis is to contribute to the still growing field of learning game research by providing detailed answers to the questions of what and how competences are enacted in these types of games through an explorative study of the empirical field of the game Homicide played in schools.

The introduction begins by recognizing the complexity of studying this type of game-based science learning environments in schools. The game media allow the creation of complex worlds designed for fictive game characters, students and teachers to interact in complex processes of problem solving and professional inquiries. The introduction asks the question of how to methodologically and theoretically approach studies of these complex worlds. I answer this question by arguing that attempts to identify and understand practices and competences in this type of games must draw on methodological and theoretical approaches that allow us to address and focus on the relations between the various human and non-human actors and elements of the complex worlds of professions enacted in schools. This approach is inspired by science and technology studies (STS) and especially the position actor-network theory (ANT). This thesis applies elements of the theoretical approach of STS and ANT to a new field: game studies. These perspectives are applied to an empirical study of the forensic criminal investigation game Homicide as played in four school classes conducted in cycles of design interventions aimed at examining what and how practices and competences emerge when the game was played in schools.

Game-based professional environments in school

In the past decade, science education has been the focus of studies and the development of a new generation of theory-based learning games (see Squire, 2002; Barnett et al., 2004; Shaffer et al., 2005; Egenfeldt-Nielsen, 2006; Magnussen & Jessen, 2006). It has been argued that active and critical learning about rich semiotic systems and the complex problem-solving that well-designed games are theorized to involve, are similar to science learning when understood as an active process of inquiry familiar from real-life science (Gee, 2004). This is in contrast to traditional science education, which has been criticized for creating little ownership or a practical
understanding of scientific processes and methods (Gee, 2003; diSessa, 2000). In spite of the boom in game learning research, relatively little is known about how science learning occurs through game-play or what interaction occurs when complex game-based learning environments are brought into a school culture.

The objective of this thesis is to provide a detailed understanding of practices and competences that are brought out in the game *Homicide*, which can be grouped as part of a new generation of theory-based learning games that simulate professional environments. One common trait that these games share is that they simulate elements of the objectives and environments in a specific profession by using and making available the technology, tools and/or methods of that profession. Some examples of simulations are environmental engineers trying to find a polluted site (Squire & Klopfer, 2007), urban planners redesigning the central pedestrian street in a town (Shaffer, 2006), or criminal investigators investigating a murder using forensic techniques (Magnussen, 2007a). The objective for creating these types of games is to apply the game media to designing complex settings based on the learning environments of real-life professionals, thus allowing students to engage in the complex, creative, and innovative problem solving and learning processes of these professionals. The motivation for developing these types of games stems from a critique of the teaching of standardized skills to children in today’s school system. The skills acquired in this system do not prepare them for a future that involves a constantly changing, complex work life (Shaffer & Gee, 2005). Critics believe that under the current system, students do not learn to deal with problems that do not have ready-made answers and that they do not solve problems using creative, innovative thinking or collaboration. The objective of designing this type of games is to use the game media to create environments with simulations of complex real-life situations where students have to think like professionals and solve problems in innovative ways just as professionals do (Shaffer, 2007).

Simulating professions is not new. Many commercial games such as *Counter Strike* or the game version of *CSI* simulate the professional practices of counter-terrorists and forensic detectives. The difference between the commercial games and this new generation of learning games is that the designs are based on learning theories and/or detailed studies of the learning processes and the tools of real-life professionals. Some of these games are also designed to meet the goals of the formal school science curriculum (Magnussen & Jessen, 2006), while others, "create the epistemic frame of a socially valued community by re-creating the process by which individuals develop the skills, knowledge, identities, values and epistemology of that community" (Shaffer, 2007, p. 164). The latter class of games is defined as ‘epistemic games’.
This thesis attempts to define what practices and competences are enacted in the game *Homicide* when played in school. For lack of a term that talks about both school and the game simulated practice, I therefore simply use the term 'game'. This less precise term refers to the intentions in the design of *Homicide* without making presumptions about the enacted practices when the game is played. The definitions of the term game are numerous and include definitions of games as exercises of voluntary control systems (Avedon & Sutton-Smith, 1971), as systems (Salen & Zimmerman, 2004), and as a form of art (Costikyan, 1994). This thesis views the concept of games in line with the definition made by Wittgenstein (Wittgenstein, 1958). Wittgenstein argues that similarities between games such as play, rules, and competition do not adequately define what games are but should be characterized as resemblances between members of the family games form. *Homicide* was designed as a member of the game family with rules and play but also, as discussed above, contains elements of the forensic profession specific to games that simulate professional environments.

**Studying complex environments of professional science practice in schools**

The empirical field of these studies, *Homicide*, is thus a complex game designed using elements of forensic police professions and game elements such as rules and play. In the following I contrast the approach applied in this thesis to the approach of game studies and didactical approaches. The approaches generally used in game research and learning game research are numerous and have, as shown, led to a variety of definitions and classifications of games. Overall, areas of this research have been critiqued for approaching game studies from either an **essentialist** or a **determinist** perspective (Hanghøj, forthcoming, 2008). From the essentialist perspective, games are understood as self-contained entities. Examples of this are found within the discipline of computer game research and include the understanding of games as systems (Salen & Zimmerman, 2004). In contrast to the essentialist perspective, the determinist perspective is criticized for approaching game studies with the objective of determining **outcomes** of games. This perspective is found particularly within the field of game learning studies based on psychological learning theories and includes studies of the learning effects of specific game designs (Egenfeldt-Nielsen, 2005). From this perspective, the adequate design and use of a game design are believed to lead to students being met with well-defined learning goals. Both the essentialist and the determinist approaches are criticized for "black boxing" educational gaming in the classroom setting by focusing either on games as isolated entities of virtual worlds or on learning outcomes (Hanghøj, forthcoming, 2008). Latour defines the concept of the 'black box' as a tool in scientific facts construction. Such facts and theories are black boxes which produce a predictable output to an input but where the inner
mechanisms of the origin of the theory such as scientific controversies or complex inner workings are hidden to the observer (Latour, 1987). The essentialist and determinist approaches are thus criticized for neglecting or leaving out the messy contexts of games played in classroom settings.

In contrast to these two approaches, the aim of this thesis is to open the black box of the game in the context of classrooms in an attempt to understand what practices and potential competences are enacted there. This approach of course increases the risk of getting complex answers, but the little we know about what competences are enacted in these new learning environments means we need a detailed understanding of the practices related to the specific contexts they take place in. The argument made here is that this knowledge can only be generated by entering the contexts with as few as possible “black-boxed” presumptions about outcomes or intrinsic qualities about the empirical field. Consequently, I approach this study with partly an explorative ethnographic approach, but only partly, as it also involves the theory-based design of the game. The design contains built in assumptions about what practices students work with that we need to attend to. *Homicide* was designed to be played over a full school week as a cross-disciplinary science and Danish language scenario. As described above, the approach here is to understand practices and competences as enacted in the context of the classes and not as an outcome answering the question “What has been learned?” But, what terms are used to define these practices in an environment designed for professional science practice in schools when the aim is to refrain from looking at learning effects and the intrinsic qualities of the game?

One related field is the field of science didactics. The Danish definitions of didactics are rooted in the German educational tradition. There are broad and narrow definitions of didactics, but overall, didactics are understood as reflection concerning education. Wolfgang Klafki defines didactics broadly as both a science engaged in investigating and describing practice as well as a generating theory which can be of help to the practitioner (Klafki, 1991). In the Danish educational tradition, didactics are often concerned with meta-discussions on the nature of didactic categories and how they are related, while discussions about goals and content are left to subject didactics such as science didactics (Schnack, 2004). In science didactics there is a tradition for discussing the goals and content of the subjects in relation to scientific disciplines (Andersen et al. 2004). A central issue in science didactics is how a specific subject as taught in schools relates to the scientific disciplines and includes discussions on whether to choose educational content because it represents the scientific discipline or because it is relevant to the student. Traditionally, the discourse of science didactics has involved science subjects such as physics and chemistry isolated in relation to the scientific discipline. Newer discussions, however, advocate understanding science didactics as
an “area didactic” that includes every natural science discipline (Andersen et al. 2004). This more recent approach is closer to the definition of scientific literacy central in the science curriculum discussions and research taking place in English-speaking countries. Overall, these discussions center on what citizens should know about science to participate in a modern democratic society as well as what goals science teaching should fulfill and how.

The topic of this thesis is related to the aforementioned discussions concerning education and science learning. As described, *Homicide* was designed to meet formal science and Danish curriculum. Unique to *Homicide* is the simulation of criminal investigations designed to enable students to experience and take part firsthand in a professional inquiry situation. The overall inquiry process or the backbone of the game was thus designed with reference to the actual professional practice and not in relation to the content of a scientific discipline. The nature of the forensic inquiry situation involves science as well as other disciplines. The goal of this study is thus not primarily to understand what science students learn in relation to science curriculum goals or if it fulfill goals for scientific literacy in general. It is an ethnographic study of what competences are enacted when a professional inquiry is played out in schools. Leaving behind curriculum goals and the standards of the formal school system as the standards for understanding this interaction of professional practice in schools, I approach the studies exploratorily by applying different theoretical lenses in the analysis of data generated in the classes playing the game.

STS concepts of inscriptional practices provide a lens for analyzing student representational practices. Inscriptions play a central role in studies of scientific practice, which defines them as tools for winning scientific disputes and establishing scientific facts (see Latour & Woolgar, 1986; Latour, 1987). The aforementioned lens sensitizes studies of scientific practice to aspects of the role of the representations. In the attempt to understand the competences enacted in creating and using representations and how they are related to inquiry processes, I draw on concepts of meta-representational competences (diSessa, 2000; diSessa & Sherin, 2000) and definitions of inquiry skills and theory-evidence coordination (Kuhn, 2005; Kuhn 2002). I return to an extended description of this approach in Chapter 1.

**Actors in game networks**

The first half of the research objectives in this thesis are concerned with defining what practices and competences are enacted in the game *Homicide*, while the second half of the research objectives ask how these practices are enacted. A look at the different theoretical perspectives discussed in the introduction show fundamentally different ways of viewing who or what enact
learning in the field of science didactics and in the learning game field. To illustrate, the following quotation by Schnack in the introduction to a recent Danish book on didactics titled *Didactics Backwards and Forwards* (Didaktik på kryds og tværs) describes what makes the variety of engagements in education in different school subjects didactic:

One cannot teach without teaching 'something', just as one simply does not 'learn', but learns 'something'. As a result, education always is intentional. Teaching cannot take place without desiring something for someone; by definition, an inbuilt objective exists in all teaching – an objective that has to do with learning. Learning can of course take place without teaching, and even when learning is a result of education, its 'something' is never identical to the objectives of the education. Nevertheless, education always contains a learning objective. Finally, teaching is always multi-dimensional. People invariably learn more than one thing at a time, partly because they often learn several parallel things simultaneously. Just as important, however, is the fact that people always learn something from what they learn – from the way they learn it. And, people learn something about learning. (Schnack, 2004, pp. 6–7 (my translation))

In sum, the above description of the subject didactic perspective illustrates the research fields focus on how human actors – most often teachers and students - teach and learn. The one that teaches always has objectives concerning their teaching; they want the students to learn something. But, students do not always learn what the teachers intended for them to learn, or they learn several things. Potentially, they learn some of the curriculum based on the way it is taught as well as something about learning. There are two actors in this universe that ‘do’ the teaching and learning – the teacher and the student.

As a contrast to this I present a quotation which illustrates how actors in teaching processes are viewed in game studies. In the article *What would a state of the art instructional video game look like?*, James Paul Gee talks about how teaching professional skills takes place in the commercial game *Full Spectrum Warrior*:

*Full Spectrum Warrior* teaches the player (yes, it is a teacher) how to be a professional soldier. It demands that the player thinks, values, and acts like a soldier to "win" the game. The player cannot simply bring conventional game playing skills, such as those needed to succeed at *Castlevania, Super Mario, or Sonic Adventure 2 Battle*, to this game. The player needs not only these skills, but others as well. In *Full Spectrum Warrior*, the player must acquire the professional skills of a soldier commanding two teams of a dismounted light infantry squad. (Gee, 2005, p. 2)
In this case, games and their elements are described as actors that do something in the teaching situation. The game *teaches* and *demands* thinking, valuing, and actions from the player as a professional soldier. In this understanding teaching and learning in games involves the interplay of actors such as the game, the player as a game character, fictive characters, other players as characters, and the many elements of the imagined and real worlds. Games and elements of games such as game characters affect our actions by posing challenges and requiring certain processes.

How do we then approach the study of these processes in schools? If learning in games is accepted as the interplay between human and non-human actors, then we must also consider the agency of the elements surrounding the computer aspect of the game *Homicide* played in the various classes. The hypothesis of this thesis is thus that when studying the enactment of practices, competences and learning in games such as *Homicide* in a school setting, we have to apply approaches which will allow us to understand how various actors and elements, including the students, teachers, a software program, game characters, the school setting, laboratories or boards take part in this enactment. The approach to studies of enactment of competences is thus inspired by STS and especially ANT. In ANT actors are exclusively defined by their relations to other actors in the network. In other words, entities such as scientific facts or a game “take their form and acquire their attributes as a result of their relations with other entities” (Law 1999, p. 3). In ANT actors are thus not defined by intrinsic qualities and can thus be human as well as non-human. In Chapter 1 I return to the description of how this perspective is applied to the current studies.

**Case: design interventions in the game *Homicide***

The empirical field work in this thesis consists of observations of the game *Homicide* being played in four schools. The game is designed for cross-disciplinary science education for lower and upper secondary school students aged 13 to 16. In a week-long investigation process, students play forensic experts solving a murder case. Part of the investigation process is to analyze clues such as the fingerprints and blood found at a crime scene using both theoretical and practical methods. The practical and analytical work is thus conducted in both the virtual game space and physically in school laboratories. This game-based learning environment was designed with the aim of supporting scientific inquiry through a simulation of elements of a professional forensic practice situation (Magnussen & Jessen, 2004). The empirical field work was carried out as a series of design interventions in the classrooms settings in which the game is played. The methodological approach in the studies undertaken is design-based research characterized by iterative cycles of problem definition, design, interventions, and analysis. Being a rather new method, terminologies
and definitions of what the conduction of the different stages involves are still being defined. One of the aims of using this method is therefore also to contribute to a discussion of definitions and terminologies.

**Research questions and overview of thesis**

This introduction to the perspective of these studies leads to the following research questions, which direct the research in this thesis:

- What practices, competences and tools are enacted when the game *Homicide* is played in schools?
- How are competences, learning and tools enacted in networks of related entities in the school settings the game is played in?

Chapter 1 describes the theoretical approach applied in the explorative study of the empirical field. The thesis is divided into three parts. In part I, which consists of Chapters 2 to 4, give an introduction to the game *Homicide* and presents how the game was developed and studied in cycles of problem definition, design, intervention, and analysis. The methodological chapters describe how the focus on student inquiry and representational methods was established through empirical studies and design interventions. Part II, which is comprised of Chapters 5 and 6, looks at representational practices in student inquiries and analyses the competences enacted in these settings partly through the theoretical lens of STS. In the final part of the thesis, Part III, which includes Chapters 7 to 9, I take on a different theoretical perspective to study how the defined competences are enacted in networks of game and school actors. Applying theories of distributed cognition, Chapter 7 looks at how competences and learning are enacted in systems of artifacts and individuals. Chapter 8 looks at the different formats of representations constructed in the different classes and then analyzes their effects on the relations and practices in the different classroom settings. Chapter 9 maps how representations are constructed in networks of related actors and analyze representations as an object in mutable versions. The discussion of the role of networks of actors in the different classroom settings continues in the discussion chapter, where I attempt to define overlapping relations and practices in the different networks of representational inquiry. I also compare the identified competences to formal curriculum goals in Denmark and discuss how they compare to methods of different professional practices.
CHAPTER 1
THEORETICAL OVERVIEW

The introduction argued that a detailed understanding is necessary concerning what practices and competences are enacted in games such as Homicide that simulate elements of professions. Entering into these studies should be done with an exploratory approach as little is still known about this type of game settings in schools and the actors of the complex worlds of professions enacted in schools. In this chapter, I present an overview of the theoretical and methodological approaches applied in the exploration of the practices observed in the classes playing Homicide. The methodological approach in the collection and analysis of data will be described in detail in Chapters 3 and 4. In this thesis, the student investigative work with representations became my focal point as a result of the empirical studies done on the game played in schools (see Part I). I use this focal point in the analysis of the specific practices, competences enacted, and the learning processes involved in the network of actors. I focus on different aspects of the practices observed in the classes playing Homicide in order to understand the different perspectives of the competences, practices and learning enacted in these settings. In Part II, I look closely at the students’ practices and how, when, and why they use representations in their investigations. In Part III, I include the student representations as an artifact or actor in order to understand what role they play in the enactment of competences and learning processes. Theoretically, a transition is made from understanding the students as the primary actors to focusing on various actors, such as representations, boards, police fiction and teachers. In Part III, Chapter 9, I also include the network of actors that the representations and inquiries are an effect of. In the current chapter, I outline the theoretical perspectives I adapt to make these theoretical moves.

1.1: Studying professional science practice in school
The object of study in this thesis is the game *Homicide*, which simulates elements of scientific methods and inquiry of police investigators and forensic experts. A brief introduction to the game will be given here as the game dynamics and elements are described in detail elsewhere in Chapter 2. The students play forensic experts solving a series of murders and the game is designed to meet the seventh to tenth grade curriculum goals of lower and upper secondary school in Denmark. The laboratory analysis of clues such as blood stains and gunshot residues are based on professional forensic techniques as well as the laboratory practices and science tasks that are part of the curriculum for this age group. The overall learning goal intended in the game design is for students to work with professional scientific practice and methods of inquiry.
Approaching the analytical phase, I had two main issues to look at. The first issue dealt with wanting to understand science practice and thinking in a game-based setting that simulates elements of professional science practice but that takes place in school. One aspect of this issue was conducting empirical school-based studies where elements of the practices and methods to be studied were originally situated in a professional context outside of schools. The second issue involved finding an appropriate theoretical lens with which to understand the practices and interaction of students, teachers and the tools I had observed students construct in course of the game. This section thus has a dual objective: 1) to describe the methodological approaches applied to analyze the students representational practices and 2) to present actor network theory as a perspective for studying agency of non-human actors such as tools created in the game Homicide.

1.11: Scientific inscriptional practices

The field of STS is a broadly defined field chiefly concerned with understanding the relationship between science, technology, politics, social relations and human values and how these elements again influence science and technology (Sørensen, 2005). The theoretical approach was defined on the background of sociological studies of scientific laboratory practices in the 1970s which were based on an understanding of science as socially embedded (Jensen, 2005). In their book Laboratory Life: The Construction of Scientific Facts, Bruno Latour and Steve Woolgar presented ethnographic field studies of scientific fact construction in a large Californian laboratory (Latour & Woolgar, 1986). The laboratory was described as a place where substances of study such as bacteria and chemical samples were transformed through networks of researchers and laboratory equipment to inscriptions such as graphs and scientific publications. Controversial at the time, they proposed the argument that laboratories primarily are text producing entities that translate material into text.

Use of inscriptions in scientific practice played a central role in the laboratory studies. In Laboratory Life, Latour and Woolgar describe how their field studies on the work of researchers demonstrate almost an obsession with inscriptions and inscription devices. An inscription device is defined as, “any item of apparatus or particular configuration of such items which can transform a material substance into a figure or diagram which is directly usable by one of the members of the office space” (Latour & Woolgar, 1986, p. 51). This includes everything from materials, apparatuses and procedures in the laboratory to figures and statements in scientific journals (Jensen et al., 2007). Focusing on the transformation and translation processes and the role of human actors and
transcription devices described in Laboratory Life, Latour and Woolgar draw on the network concepts and analytical approach that later came to characterize ANT.

The reflections on the role of inscriptions are part of a larger argument on how scientific facts are constructed. Latour suggest in the paper Drawing Things Together an approach to understanding the central role of inscriptions in western scientific fact construction. He bases the argumentation on the question: Who will win in an encounter between two authors building each their statement? Latour’s seemingly simple answer is, “The one able to muster on the spot the largest number of well aligned and faithful allies” (Latour, 1990, p. 23). The focus on inscriptions is thus grounded in a more extensive argument that draws upon power analyses of Western scientific culture. Latour argues that the use of inscriptions is an important strategy used in Western scientific culture to recruit allies. The enormous success of Western scientific culture compared to folk knowledge is due to what Latour calls “immutable mobiles” which he defines in the following way: “In sum you have to invent objects which have the properties of being mobile but also immutable, presentable, readable, and combinable with each other” (Latour, 1990, p. 26).

Immutable mobiles can be moved around in communities or to distant places without changing shape – or mutating, for example, in the form of scientific publications, graphs or maps. Physically, the shape remains the same but it is also thought of as a network of stable relations. In STS, mutable mobiles are a tool for looking at control from a distance, but they are also seen as a way of explaining how facts move around in scientific communities and how the immutability of these facts are secured. John Law, another founder of STS, and Vicky Singleton use the examples of codes, information, or texts such as orders, newspapers and money orders:

...- If objects such as these are able to hold their relational shape as they circulate around the globe, then long distance control is a possibility. The later, then depends upon such immutable mobiles. It depends upon a process in which networks of relations are built up to secure immutability on the one hand, and mobility on the other (Law, & Singleton, 2005, p. 335).

For immutable mobiles to be a tool for long distance control, or used in scientific disputes, a two-way connection between the represented object and the immutable mobile has to be established. The network of relations they consist of has to support immutable mobiles being able to represent objects. In STS and ANT, the concept of translation is central in describing how these networks of relations come into existence.
I ANT the concept of translation is defined as: "the process or the work of making two things that are not the same, equivalent" (Law, 1999, p. 8). The term is broadly used to describe the process by which actors gain strength by associating themselves with and speaking on behalf of others (Callon, 1986). A union representative, for example, speaks on behalf of a group of organized workers, and a politician speaks on behalf of members of a party. It is argued that these actors gain strength because in the network of relations, they represent a chain of other actors. These individuals have to be elected and statements have to be decided upon in meetings with other representatives, etc. An actor speaking on behalf of other actors is not necessarily a person. A scientific publication can be based on publications by other authors, tests using laboratory rats, or measurements using laboratory devices. In terms of translation, the publication speaks on behalf of other actors. In classic STS, and specifically in the position ANT, analyses focus on how actors such as scientific publications gain the strength to be allowed to speak on behalf of other actors (Jensen, 2005). In summary, Latour argues that in analyzing scientific practice one should take writings and inscriptions into account but not believe in the power of isolated signs and symbols (Latour, 1987). Latour emphasizes that power structures are central in this context and not the anthropology of writing historical accounts of visualization. Focus should be on the way actors use documents, signs, prints or diagrams in disputes, and on the aspects that help ensure the alignment of new allies in the disputes. Latour writes, “We need, in other words, to look at the way in which someone convinces someone else to take up a statement, to pass it along, to make it more of a fact, and to recognize the first author’s ownership and originality” (1990, p. 24).

STS’s definition of scientific inscriptive practice and immutable mobiles provides me with a lens through which to examine student work with representations in the simulated professional science practice in *Homicide*. Through this approach I seek to understand what processes are involved in the construction of representations, and how representations are used for presenting and investigating the cases. I attempt to understand the representational practices of the first class I observed by aligning their practices with the inscriptive practices as defined by STS. Applying this approach, however, has several implications. In the first two analytical chapters, Chapters 5 and 6, the human actors and their practices are the foreground of the studies. As a result, I do not grant human and non-human actors equal amounts of attention in the first half of the analysis. This theoretical choice derives from the aim of studying both practices but also the competences students enact in this framework. As a network theory focused on how related actors perform in practice, STS and ANT do not offer a perspective that is applicable for analyzing student competences in this thesis; hence, I combine the Latourian definition of inscriptive practices with
frames for looking at representational and inquiry competences and learning. An outline of this will be introduced later in the present chapter.

Investigating the representations by aligning them with definitions of immutable mobiles also has limitations for how we understand the object being studied. By applying the classic STS perspective to the studies of student representational practices and created representations, they are viewed as stable objects and as tools in disputes between human actors. As shown, stability and stable objects used as a tool for keeping control play a central role in classic STS. To open the study for understanding mutable and process-oriented qualities of practices and competences the thesis draws on concepts of “after ANT”.

1.12: Actor-network theory

This chapter describes the theoretical background for understanding competences as enacted in networks of human and non-human game and school actors. Concepts of classic ANT, such as mutable mobiles and translation, have already been introduced in the previous section. Here, the central concept of actor and the ANT network metaphor are introduced as well as critiques from so-called ‘after ANT’ authors of the classic network understanding. The central concept of “fluid” developed in after ANT, is also presented.

Classic ANT: Network and actors

ANT was defined as a position in STS in the 1980s by Bruno Latour, John Law and Michel Callon. Like STS, ANT can be described as a sociological analysis of science and technology. But, ANT contributes with a radical relational network understanding rooted in semiotics. Law argues that ANT should be understood as a semiotics of materiality, stating, “It takes the semiotic insight, that of the relationality of entities, the notion that they are produced in relations, and applies this ruthlessly to all materials – and not simply to those that are linguistic” (1999, p. 4).

In classic ANT, networks are thought of as interrelated entities – or actors – which have been successfully translated by other actors (Callon, 1986). Actors are exclusively defined by their relations to other actors in a network. In other words, entities such as scientific facts or games “take their form and acquire their attributes as a result of their relations with other entities” (Law 1999, p. 3). The actor is thus both the network and a point in the network (Callon, 1986). This radical relational network understanding implies that entities are not defined in terms of inherent qualities, but solely in terms of relations to other entities. ANT makes no distinctions between human and non-human, micro and macro, or agency and structure. This is not because the theory
does not recognize such divisions or distinctions, but because they are seen as outcomes or effects of the network (Law, 1999). The lack of predetermined categories in ANT studies implies that actors do not necessarily have to be human. Actors are defined by Latour as something that acts, or gets activity from another actor:

An “actor” in ANT is a semiotic definition – an actant -, that is something that acts or to which activity is granted by others. It implies no special motivation of human individual actors, nor of humans in general. An actant can literally be anything provided it is granted to be the source of an action’ (1996a, p. 373).

This opens up for a radical new understanding of actors. Bacteria, a theory, an electron or humans can all be understood as actors in ANT. To avoid confusion, the term actants or entities are also used to describe the knots in the network that act or are granted activity (Jensen, 2005). ANT does not distinguish between the network and the actors. Classic ANT sees actors as networks of relations which, from a certain perspective, have stabilized. Studies of how facts are constructed through networks of human and non-human actors are examples of this.

In classic ANT, the analytical focus is on how actor networks are constructed and stabilized, and on how actors are able to recruit allies, keep them loyal, and gather strength to speak on their behalf. The stability of networks and why some networks become stable and others fall apart are central themes in these studies (Jensen, 2005). The definition of actor and network is formulated in opposition to the social sciences of the 1980s. Latour later states how the word theory in ANT is misleading (1999b). ANT is not a theory of the social aspects, but a “very crude method to learn from the actors without imposing on them an a priori definition of their world-building capacities’ (Latour, 1999b, p. 20). Latour states that the “ridiculous poverty” of ANT concepts such as translation and allies was a way to signal that its vocabulary could not replace the rich vocabulary of actors. Latour rejects the critique that ANT is descriptive and argues that only by making the vocabulary even vaguer will the actors be heard.

**After ANT**

Classic ANT has been criticized for its focus on power strategies and stabilizing processes in networks (Law & Singleton, 2005). This focus might make sense when speaking of the construction of scientific facts or texts constructed in stable networks with set procedures. When looking at technologies such as games, analyzing them solely in terms of the stabilizing network metaphor becomes less obvious. Games continuously develop and reconstruct. Game companies have to add new worlds or construct new versions of games to be able to keep players loyal. In addition,
players change rules, program game elements, and build networks of fan sites. The game technology and game developers have to be able to adapt to these changes and changed usage to survive. Hence, the strength of some technologies seems to be their ability to adapt to new practices and relations rather than support stable procedures.

The mutability of objects and the multiple orders of objects are central themes in what has been called “after ANT”. Annemarie Mol and John Law are the prime contributors to developing metaphors for empirical descriptions of these kinds of objects (see Mol, 2002; Law & Singleton, 2005). In this thesis I draw on the metaphors of network and fluid in the empirical analysis of representations constructed in the game and the relations and practices by which they define and are defined. These metaphors make it possible to create empirical descriptions sensitive to patterns of relations and practices in the different settings I have studied.

The fluid metaphor and multiple enactments of objects

The fluid metaphor was developed based on a critique of the focus of stability in descriptions of objects. A central example of this is the discussion by Marianne de Laet and Annemarie Mol in the paper *The Zimbabwe bush pump: Mechanics of a fluid technology* (de Laet & Mol, 2000). De Laet and Mol describe how technologies can be understood as mutable both in terms of mechanical adaptations for use in communities and in terms of gradually changing the practices and relations that define the success of the technologies. They argue how these kinds of technologies can be understood as “mutable mobiles”, the definition of which arises from a critique of Latour’s concept of immutable mobiles (Latour, 1990). Their definition of the pump as a fluid actor differs from the classic ANT definition of actors as a stable set of relations. The focus of this critique is that attention must be paid to the mutability as well as what makes objects stable and immutable if objects and actors are to be understood (Law & Singleton, 2005). A detailed description and examples of mutable mobiles are provided in Chapter 8.

I draw on the metaphor of fluid patterns of relations to analyze changes in the different formats of representational design and practice observed in the classes playing *Homicide*. By drawing on the metaphors of a fluid pattern of relations, the aim has been to produce studies sensitive to how practices defined and were defined by these changes.

Another element for investigation is the different formats of representations constructed in the different classes. In this part of the study I attend to the second research question: How are competences, learning and tools enacted in networks of related entities in the school settings the game is played in? This use of the word “enacted” in this thesis is inspired by Mol’s concept of
multiple enactments of objects. This concept is based on the argument that an object can be understood as multiple entities due to the multiple practices and relations in which it is enacted. In her book, *The Body Multiple*, Mol uses the example of diagnoses and the treatment of diseases in the medical system. She argues that different diagnoses of a disease should be understood as different enactments of the disease in the different relations and practices. The disease thus does not exist independent of the practices that manipulate, articulate and define relevant actions to be taken in relation to it. The implication, Mol argues in *The Body Multiple*, is that the body, which usually is viewed as one object, can be seen as multiple entities due to the multiple practices and relations it is enacted in. As a result, a variety of networks exist that produce different versions of a phenomenon depending on what practices they are enacted in. The analytical focus should be on understanding these different versions and their overlapping relations, effects and practices (Gad & Jensen, 2007).

I return to this discussion and provide a detailed description of examples of these concepts in Chapter 9. In line with the above definitions the representations and practices are in Chapter 9 analyzed as *enacted* in networks of relations and practices. I thus draw on the above concepts in analyzing representations in terms of the relations and practices they are an effect of. I draw on the definition of objects as patterns of relations (Law & Singleton. 2005) in the analysis of what actors in different settings *Homicide* is played in influences on the students representations. As a network theory, the ANT perspective does not, however, provide a lens with which to study competences or learning processes. In the next section I describe the theoretical approaches made to investigate this.

### 1.2: Studying competences and learning in networks

In this thesis, I attempt to understand both what competences are enacted when the game *Homicide* is played in schools and the role of representations in the enactment of competences and learning processes. The next part of the theoretical chapter is thus divided into two sections, one that provides a description of the theories drawn upon for the study of competences, and one that provides a description of the theories used for studying learning processes in a network perspective. Competences can be studied and understood from various perspectives: as abilities, enactment, and outcome. This thesis takes partly an ethnographic approach to studying what competences and how these are enacted in the classes playing *Homicide*. In these studies competences are therefore studied and understood as students’ capabilities, related to representational and investigative practices, enacted in play of Homicide. This definition is further described in Chapter 6.
Epistemology and representational competences

In the study of competences, I am inspired by the notion of epistemology (Shaffer, 2007). David Shaffer defines the epistemology of a discipline as a “particular way of thinking about or justifying actions, of structuring valid claims” (Shaffer, 2007, p. 32). Professionals from different disciplines use different rules in structuring their arguments and in deciding whether something is true. I use this concept to broaden the study of competences in order to move studies of competences from a practice level to an epistemological level. In studying representational practices, I focus on practices enacted in the concrete setting in classes and align them with epistemologies of inscriptive practice in science. I attempt to broaden the study of competence by including these aspects of thinking within a profession. Shaffer argues how the work of professionals are organized around what he calls “epistemic frames” which is defined as collections of skills, knowledge, identities, values and epistemology that professionals use to understand the world from within a profession (Shaffer, 2007). As described earlier the approach in this thesis differs from Shaffer’s approach in its attempt to understand competences as enacted in networks of actors in the setting the game is played in. In Homicide the network could consists of the school, professional, and game related actors. To try and understand what the competences, values and epistemology of these communities are, I align representational practices to both inscriptive practices as described in STS (as described above) and the school practice of meta-representational competences (diSessa, 2000; diSessa & Sherin, 2000). This does not, however, provide me with any perspectives on the investigation processes the representations are used for. In order to understand them, I draw on theories of inquiry skills (Kuhn, 2002; Kuhn, 2005).

To identify the inquiry in relation to the representational practice, I draw on Dianne Kuhn’s model for defining inquiry skills as theory-evidence coordination (Kuhn, 2005). Defining what inquiry skills imply and understanding what abilities people have for engaging the skills in investigations concerning how forces in complex constellations in the world act on one another as causes and effects are central in her book, Education for Thinking. A cornerstone of inquiry is, according to Kuhn, the thesis, or question, and the evidence that bears on it. Kuhn argues that gaining control of the process of theory (as “what makes sense to me”) and evidence (as sources of knowing) coordination is central in developing inquiry skills.

Kuhn defines three stages in inquiries: The inquiry phase, the analysis phase, and the inference phase. These phases will be described in detail in Chapter 6. I use Kuhn’s model in Chapter 6 for
analyzing the phases of the students’ inquiry in the game. One primary aim in using the model of theory-evidence coordination is also to understand at what stages in the inquiry students use representations and for what purposes, as well as to understand how the different representational formats support inquiry at different stages in the game.

**Learning in systems of individuals and artifacts**

Where the first objective is to understand representational and inquiry practices and competences enacted in *Homicide*, the second objective is to understand how these are enacted in networks in the school settings the game is played in. Being focused on understanding practices and relations in networks of actors the ANT perspective does not provide an approach for studying learning processes. In the next section I describe the theoretical approaches made to investigate this.

Theories of distributed cognition offer a network understanding of learning processes. Edwin Hutchins’ theory of distributed cognition offers a perspective for understanding the role of representations in the knowledge construction of students. The fundamental idea in Hutchins’ theory is that cognition is socially distributed and situated in a socio-cultural world (Hutchins, 1995). In his book, *Cognition in the Wild*, Hutchins argues that cognition (defined as “information processing”) takes place in a system of humans and artifacts that enact learning together. With this perspective Hutchins approaches learning as the adaptation of structures in the individual and in the culture. The theory is based on empirical studies of navigation on large ships. Hutchins contends that in the determining the ship’s position, the spatial relationship of the ship to the world is propagated over a number of representational media: The point on a scale of a measuring instrument becomes a command and then notes in a logbook. The spatial relationship of the ship to its environment travels through these representational media until the position is plotted on the chart. This relationship is able to propagate over representational media because of structures which bring them into coordination with each other. The concept of “mediating artifacts” is established as structural elements that mediate the relationship between the performer and the task. The mediating artifacts should therefore be understood as structural elements that are brought into coordination in the processes involved in performing tasks. Hutchins, who approaches learning as the adaptation of external and internal structures in the individual, writes:

> The processes by which an individual learns to perform the task can be seen as the propagation of a wave of organization moving across a complex set of media. Organization propagates from external media to internal media and back to external media. The changes that happen inside an individual as a consequence of learning are adaptations in a part of a larger dynamical system to organization or structure that is present in other parts of the system (1995, p. 310).
I draw upon this notion of cognition and the concept of mediating artifacts to understand the role of the student representations in the enactment of competences in systems of game and school related actors. I also attempt to identify how learning about the criminal case takes place in the construction and use of representations. In Chapter 7 I return to a detailed description of this theoretical perspective as well how it is applied to the studies in this thesis.

1.3: The use of the term “representations”
In this thesis, I have established a empirical focus on student constructions and the use of representations in their investigative process. The term representations are used to describe the maps or diagrams the students produce during the game. The obvious question here then becomes: Representations of what? The answer to this question that emerged during the observations was vague: They were representations of the student inquiry processes. A more qualified answer to this is of course part of what I seek to understand in this thesis; hence, at this point, I need a term for these objects that will open up the investigation by defining the borders of the landscape studies that does not simultaneously limit the investigation with narrow predefined concepts. Concerning the situated nature of representations, and how they are examined in STS studies in the book Representations in Science, Lynch & Woolgar write:

The organisation, sense, value, and adequacy of any representation is “reflexive” to the settings in which it is constituted and used (...). “Reflexivity” in this usage means, not self-referential nor reflective awareness representational practice, but the inseparability of a “theory” of representation from the heterogeneous social contexts in which representations are composed and used.
(Lynch & Woolgar, 1990, p.11 - 12).

Using this approach to study representations includes more than studies of the “explicit instructions and justifications” (Lynch & Woolgar, 1990, p.12), and requires a central focus on the way representations are put together, discussed, selected, placed in arguments, and “‘read’ in light of the vicissitudes of a practical situation” (Lynch & Woolgar, 1990, p.12).
I use this definition of representations and study them as “situated processes of knowledge-production” (Lynch & Woolgar, 1990, p.4), inseparable from the context in which they are produced and used. Thus, it is not the isolated nature of representations that I study but the situated use of representations – as integrated in an activity. My hope is that the studies in this thesis will bring me to a more precise definition of the representational artifacts constructed by students in the game Homicide.
PART I
DEVELOPING AND STUDYING THE GAME HOMICIDE

This thesis builds on a pre-story of the construction of the game Homicide. Part I presents the game, elements of how it was developed, and the empirical field work. The first chapter, Chapter 2, briefly explains elements of the game important to the later analysis. Next, Chapter 3 reports how the game was studied in cycles of design, intervention, analysis, problem definition and redesign and what suppositions were built into the game. I also discuss the design-based research methodological framework in relation to learning game development and what challenges this might present. In this thesis, design-based research is understood as a methodological framework and Chapter 4 describes what methodology was included in the different phases of design, intervention and analysis.
CHAPTER 2
INTRODUCTION TO THE GAME HOMICIDE

This chapter provides a short introduction to the game *Homicide*, and it gives a description of the game as it was designed to be played in the classroom. The description focuses on representational elements in the game design as well as how teacher participation was intended, as these two factors was established as focus points in the observations of students playing the game (see Chapter 3 and 4). The chapter ends with a description of the learning objectives of the game.

2.1: The content and flow of the game
Published by Malling Beck, a scholastic publisher, *Homicide* is an IT-supported game in which participants role play as forensic experts. The game was created by a development group at Learning Lab Denmark (including the author of this paper). Playing five or six hours a day, the game takes one week to play completely. *Homicide* uses a combination of doing work in investigative groups (students work on their own individual case) and holding meetings in which groups share information about their cases. The chief of police, i.e. the teacher, encourages students to set new goals for their investigation. First, the class is split into groups that play a simplified three-hour introductory case to become familiar with the setting, the interface and the central forensic techniques. The whole class solves the same case but is given directions to use different techniques such as DNA fingerprinting or fingerprint techniques. The different groups thus become specialized in one technique. After the class has solved the intro case, the students form new groups. The intention with this is that their should five experts on five different techniques in each group. The new groups receive new logins and are then able to login to the interface that contains their main case which should take them the remaining four days to solve. They first have 15 to 20 minutes to gain an overview of the information in the case and answer the questions: who died, how and when it happened and who the central characters in the case. After having established this first overview of their case the groups briefly present their case to the class on a meeting led by the teacher. The game consists of the phases outlined in table 2.1 below.

<table>
<thead>
<tr>
<th>1. Group work:</th>
<th>The students login to their main case with the aim to gain an overview of the case.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overview established</td>
<td></td>
</tr>
</tbody>
</table>

37
1. Status meeting: 
Brief introductory meeting 
The students give the other groups an overview of their case based on the questions: Who died? Where did it happen? Who are the suspects?

2. Group work: 
preparation for the press meeting 
The students work at getting information about the case and the characters involved. The work involved in this phase includes the analysis of interrogations and the technical analysis of clues found at the crime scene. Students also have to prepare which information they will present to the public at a press meeting.

2. Press meeting 
The groups take turns acting as police investigators at a press meeting in which the rest of the students act as journalists who ask penetrating questions.

3. Group work: 
Technical analysis of clues 
The students work to obtain information about the case and the characters involved. In this phase, the work includes the analysis of interrogations and a technical analysis of clues found at the crime scene.

3. Status meeting: 
Presentation of hypotheses 
The students present how their case is developing, including, for example, new knowledge about new suspects, events or clues. They also present a preliminary theory on who committed the murder. The data presented are questioned by the teacher and the other groups of students.

4. Group work: 
Preparations of reconstructions 
Aside from the analysis of clues and interrogations, students work with substantiating or discarding various hypotheses. The groups also prepare reconstructions of the crime.

4. Crime reconstruction 
The students present a reconstruction of the series of events leading up to and after the crime. They also present their theory on how the victim was murdered and by whom.

5. Group work: 
Preparation of Indictment 
The groups are given access to the final interrogations, providing them with the opportunity to see if their theories can be confirmed or denied. The groups make an indictment and determine the penalty for the offence based on current legislation.

5. Final meeting 
The indictments are presented and discussed.

Table 2.1: An overview of the various phases in the game Homicide. Meetings are held in present of all groups and their teachers. (The information in the table is retrieved from the teacher’s manual which is part of the game material). After each meeting, the teacher grants computer access to new parts of the game, thus providing the investigators additional information to work with. The game ends with the groups presenting their theories to the other teams and writing an indictment based on the evidence and testimonies of suspects and witnesses. The interaction during the game is intended as primarily between students in the classroom and not chiefly computer-student interaction as is the case in most computer games. Instead, the computer is used as an extended police database.

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1 Retrieved in Danish from http://drabssag.emu.dk/ on February 17, 2008
The game’s interface provides the players access to videotaped interviews with suspects, reports from the local police, maps, photographs, illustrations and text describing evidence found at the crime scene. With this information at hand, the players have to plan their investigation process. The investigators analyze the evidence through laboratory work and analytical processes using the technological, scientific, theoretical and practical methods available in the Forensic Handbook that is part of the game. Some of the work involved here includes pen and paper tasks and some practical analysis in the school laboratories. An example the laboratory work includes the chemical analysis of samples from a suspect’s hands to determine whether there is evidence of gunshot residue, an indication that the suspect recently fired a gun. One objective of the game is for students to learn how to handle different types of data and to use different skills, including critical thinking when they analyze interviews with the suspects, and empirical competencies in handling the data from the technical investigations.

The game material also provides tools that can be made to assist the different processes. The figure below shows an interface that contains graphics showing a gallery of characters, including the deceased, with their names and a short description of how they are connected to the deceased.
Picture 2.2: Gallery of characters in the Marie Johansen case. A drag and drop feature allows players to move the pictures around.

There is also a concrete example in the case file that demonstrates how students can make their own galleries, as shown in Picture 2.3.

Picture 2.3: A template of how a character gallery can be made. The template is part of the students case file. It is suggested that the students print and group character profiles into three groups: suspects (left), non-suspect (right), and victim (center, top). The fourth category is for knowledge that has not been connected to any characters (center, bottom).
The example in the game recommends printing out the profiles (a sheet listing the characters’ personal data and a photo, as shown in Picture 2.4 below) in the game material and using them to build the gallery of characters.

In the instruction manual, the teacher’s role is primarily defined as that of a helper and an initiator\(^2\). The teacher has access to all the answers and should advise students by asking open-ended questions that help players focus and get back on track if they get stuck in the investigation process. The pupils can obtain the data they need from the police database, but the teacher is still in control of what is released at what point in the game. The manual also encourages the teacher to play the role of the chief investigator who advises the investigators, but who lets them make the decisions. The chief sets the agenda at the status meetings where each group gives reports to one another and asks critical questions about the continued investigation. The teachers are advised to work on striking a balance that allows them to play their roles to an extent that comes naturally instead of not playing the roles at all. The instruction manual reminds teachers that the pupils identifying with their roles can be disrupted if they have to step out of their roles and resume being pupils whenever they speak to the teacher. The manual also stresses the importance of maintaining the illusion throughout the game that the pupils are executing something important in solving the cases because doing so preserves their motivation for conducting the investigation process.

\(^2\) The information is retrieved from the teacher’s game manual which is part of the game material. A description of the elements presented in this chapter can retrieved from http://drabssag.emu.dk/.

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![Picture 2.4: Character profile for suspect Poul Berg. The file appears by clicking on the picture of Poul Berg in the character gallery (see Picture 2.2). The profile lists the characters’ personal data and provides details related to the deceased in the case.](image)
2.2: The intended learning goals

One of the main theoretical inspirations used in designing *Homicide* was the concept of situated learning (Lave & Wenger, 1991), where learning is situated in the social context it is part of. This notion is based on the concept of apprentice learning, where the apprentice learns through participation in a specific practice and gradually becomes a member of a community of practice (Wenger, 1998). The game design was thus inspired by the notion of situated learning, but being a simulation of a practice, it did not support learning in situ in the authentic context the simulation was based on. Lave and Wenger argue that communities of practice are everywhere, whether it is in schools, in professions or at home. The aim of the design of *Homicide*, though, was to bring elements of the authentic practice of forensic science, originally situated in the context of police work, into the classroom. Throughout the development process, the approach was thus to simulate the working processes and the techniques used by police investigators and forensic scientists. This objective of bringing elements of professional practice into schools was accomplished using two types of design strategies. On a concrete level, the methods used to analyze clues, e.g. fingerprint techniques and chemical tests for gunshot residues, resemble as much as possible the methods of real forensic professionals and experts. The actual technical tests were developed using descriptions of original techniques from forensic handbooks and with help from retired police investigators. The students, who had possibly been exposed to police methods via movies and TV series, would thus have the opportunity to use professional tools. The expectation was that this would enhance the feeling of authenticity and boost their motivation. The game, however, was also designed to meet official curriculum goals for science education at the lower and upper secondary level in the Danish school system. To ensure this, a group of science teachers assisted in designing the different tasks and technical analyses in the investigation so they were consistent with official curriculum objectives. An example of this is the DNA fingerprinting analysis in the game which is designed to meet the goal of students acquiring skills that enable them to relate to using modern biotechnology as well as to learn about its significance for the individual, society and nature in accordance with the curriculum goals of biology for lower and upper secondary schools in Denmark (Hansen, 2006). The specific methods used for the technical analyses of clues were thus designed using descriptions of professional techniques and the science curriculum goals for lower and upper secondary schools in Denmark.

Apart from the use or simulations of professional tools in the concrete tasks in the game, the game is also designed to support work with professional investigation methods on a general level. The overall goal of the game was that it should support practice of inquiry processes as the basis of
professional scientific investigation. The descriptions and definitions of “the process of inquiry” are numerous, but the process is typically described either in terms of broad definitions stating the objective of doing inquiries or by referring to the behavior involved in participating in the inquiry process (Randol, 2004). The latter type of definition, which was used to define the process in *Homicide*, can both refer to the skills involved in the inquiry process or to a characteristic of the collective process. Below, Table 2.1 lists the actions associated with doing inquiry in the main part of the literature on the subject.

<table>
<thead>
<tr>
<th>Action</th>
<th>Inquiry Process</th>
<th>Collective Process</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asking a question</td>
<td>Making a prediction</td>
<td>Investigating</td>
</tr>
<tr>
<td>Controlling variables</td>
<td>Making an observation</td>
<td>Collecting data</td>
</tr>
<tr>
<td>Planning a procedure</td>
<td>Finding flaws</td>
<td>Drawing conclusions</td>
</tr>
<tr>
<td>Explaining results</td>
<td>Generalizing</td>
<td>Stating a theory</td>
</tr>
<tr>
<td>Reasoning carefully</td>
<td>Making connections</td>
<td>Supporting claims with evidence</td>
</tr>
</tbody>
</table>

Table 2.1: List of actions associated with doing inquiry (retrieved from Randol, 2004).

‘Inquiry’ was defined rather traditionally at this stage of the development of the game as a series of different steps the students should go through in their investigations: problem definition, establishing hypotheses, conducting investigations, making observations, collecting data and explaining results. The development team and I tried to incorporate structures which would support work with professional inquiry methods on an overall level. The goals of designing an environment for inquiry were closely integrated with the fictional investigation process of the game. An example of this is the series of meetings built into the game where students describe the case they are investigating at the initial meetings, and then at subsequent meetings they present more and more complete hypotheses and data to verify their theories. The initial research focus during the first observations was thus to understand if the game supported inquiry processes and what types of processes we would see enacted in the classes playing the game. In Chapter 3, I return to descriptions of the game development process and the related establishment of focus in the initial observations made of *Homicide* being played in various school classes.
CHAPTER 3
DESIGN-BASED RESEARCH IN THE STUDY OF HOMICIDE

Design-based research was used in the present study as a strategy for developing and generating data on the play of the game Homicide in various school classes. In this chapter, I reflect on design-based research as a research approach and how it can be applied to learning game development. It is described how the game Homicide was developed and studied in iterative cycles of problem definition, development, intervention, and analysis. Finally the chapter presents reflections on the contribution of this research approach to the development of insights in this project.

3.1: DBR in studies of learning technology
The definition of the DBR method or research approach originally arose out of a need to find methods to study ways of using educational technology in classrooms and to gain insights into constructing successful designs (Collins, 1992). This approach was grounded in a critique of the lack of systematic knowledge the introduction of educational technology into schools had provided. It was argued that constructing a systematic science of how to design educational environments to guide future innovations of educational technologies was necessary. This design science should “determine how different designs of learning environments contribute to learning, cooperation, motivation, etc.” (Collins, 1992, p. 15). DBR or design experiments were also defined in contrast to the American classic learning theorist studies of subjects in controlled laboratory environments. In contrast to this, the design scientist’s role was to “engineer innovative educational environments and simultaneously conduct experimental studies of those innovations” (Brown, 1992, p. 141).

Design-based studies are described as an approach to study learning in real contexts to create a greater understanding of what is called the learning ecology - a complex interacting system involving mutable elements of different types and levels (Cobb et al., 2003). The researcher addresses the complexity of educational settings in designing elements of the learning ecology and of anticipating how they function together to support learning. The research approach is ideally described as a process of continuous cycles of design, enactment, analysis and redesign (Design-Based Research Collective, 2003). These research cycles entail both ‘engineering’ particular forms of learning and systematically studying them within the context defined by the means of supporting them (Cobb et al., 2003). In the literature, this design-research approach is labeled in different ways, where the names often being used are design experiments or design studies. Being a fairly new research approach, the terminology is still in the process of being established (Van den Akker
et al., 2006). In the current study, I use the term design-based research (DBR) to emphasize the focus on the research aspect as well as design.

DBR blends empirical educational research with the theory-driven design of learning environments (Design-Based Research Collective, 2003). As a result, the method is for both engineering learning environments and developing domain specific theories. In praxis though, as I will discuss later in this chapter, this research-design process can be unbalanced and end up with an emphasis on either the design process or the generation of theory. The discussion of this balance is central in DBR literature. Cobb, et al. emphasizes how design experiments should be conducted to develop humble theories that target domain-specific learning processes:

> Beyond just creating designs that are effective and that can sometimes be affected by “tinkering to perfection,” a design theory explains why designs work and suggests how they may be adapted to new circumstances (Cobb et al., 2003, p. 9).

One of the strengths of DBR has been described as its method’s capacity to serve as a framework for combining and integrating various research methods at different phases of research and development (Squire, 2005). This is central in the broad definition of educational DBR offered by Barab and Squire (2004):

> Design-based research is not so much an approach as it is a series of approaches with the intent of producing new theories, artifacts, and practices that account for and potentially impact learning and teaching in naturalistic settings (Barab & Squire, 2004, p. 2).
As a fairly new method, there are as many different definitions of how to design, conduct and analyze design experiments as there are practitioners. Consequently, examining a few specific examples of utilizing DBR in educational research is valuable. In this review, I focus on examining a variety of reflections on and methods used at the different stages in the DBR process as well as the role of the researcher. As will become evident, the borders between the different phases in DBR are fluid and intertwined. Nevertheless, I attempt to group the authors’ experiences under the following three categories: 1) preparing for a design experiment, 2) conducting a design experiment and 3) completing a retrospective analysis. This structure is based on the work of Paul Cobb and Andrea diSessa (Cobb, et al., 2003).

### 3.11: Preparing for a design experiment
Cobb and diSessa are important contributors to the development of this method for educational studies. In their article, *Design experiments in educational research*, the authors specify what is involved in preparing for and conducting a design experiment, as well as completing a retrospective analysis (Cobb, et al., 2003). In classrooms most design experiments are constructed "as cases of the process of supporting students learning in a specific content domain" (Cobb, 2003, p. 11). The theoretical intent in most design experiments is to identify and account for successive patterns in student learning by relating these patterns to the means by which they are supported and developed. The research team must therefore specify which disciplinary ideas and forms of reasoning constitute the goals or endpoints for student learning.

Kurt Squire, who describes the concrete challenges in using DBR for designing learning games, argues in his paper, *Design research for game-based learning*, that DBR approaches are not particularly new, but rather, that DBR “offers new ways for thinking about mixing research methods, dealing with complexity in learning environments, and accounting for the role of the researcher in educational technology research” (Squire, 2005, p. 9). He uses specific examples of game development and research to suggest relevant frameworks using various methods for different types of cases and at the various stages in the DBR process.

Squire describes and categorizes two particular cases. The first case is an example of a program where researchers wanted to investigate a game-based learning environment that did not exist. In designing and researching a learning game, they wanted to explore the hypothesis that games “are a powerful, untapped medium for learning” (Squire, 2005, p. 9). According to Squire, they needed to understand both the pedagogical potential of the medium as well as the factors supporting or inhibiting this potential in the classroom, such as gender and classroom activities, in order to
investigate this. One approach used by researchers to investigate this involved the utilization early in the process of story boarding, which was presented to students and teachers.

In the second case described by Squire, the research process did not involve designing new technologies or testing new types of teaching. Squire explains that the researchers wanted to study the potential of using commercial computer games in education. He also emphasizes that DBR is a unique method in this type of case because it is “a commitment to understanding learning and instruction in authentic contexts and improving a program through iterative experimentation” (Squire, 2005, p. 7).

3.12: Conducting a design experiment
The first design process takes place during the phase of conducting the design experiment. After the initial processes, the challenge is in this phase to “formulate a design that embodies testable conjectures about both significant shifts in student reasoning and the specific means of supporting those shifts” (Cobb et al., 2003, p. 11). Cobb et al. describe how researchers in well researched areas have a solid idea of whether their conjectures will hold. In less well researched domains, they consider their conjectures as being speculative and begin their studies with the expectation that the conjectures will prove to be unviable.

Squire describes a concrete example of this in the description of the design process involved in designing the educational game Supercharged (Squire, 2005). In this phase of the research, the researchers went through iterative cycles of design, intervention and redesign. Initially, they designed prototypes of educational games that would address questions in both education and game theory. At the next stage, they shared the prototypes with students, teachers and game designers and used qualitative methods to observe how different groups reacted to the educational games. After these two stages, the group went through cycles of building prototypes and testing them by interviewing students and teachers while they were playing the game in an attempt to examine the players’ thought processes during the game. This revealed that students did not let go of their misconceptions about the basic physics concepts the game was constructed to teach them. Consequently, the researchers created a series of game levels that would challenge these misconceptions and tested them using a variety of qualitative methods (field notes, videotaping classroom interactions, clinical interviews) and quantitative methods (pre- and post tests). In this phase of the project, apart from carrying out tests on how learning through a game-based unit compared to an inquiry-based method, pre- and post tests and interviews were used to test for conceptual understanding.
This example of how researchers have to discard elements of design is explained by Cobb et al. as
the dual nature of design experiments, which has a projective and a reflective aspect (2003). Regarding
the projective aspect, researchers implement a design with a hypothesized learning process and with
the means of supporting it in mind. The reflective aspect of the methodology is that it is conjecture
driven. The initial design is a conjecture of how to support certain types of learning. During classroom
studies, for example, the conjecture can be changed or refuted as the researchers learn from observing
student interaction with the design. Researchers use the iterative design process to subject
conjectures to tests in the classroom, and the new conjectures developed as a result in these cycles
of invention and revision. This requires the researchers to be sensitive to evidence of learning.
The outcome of this cycle is an explanatory framework that specifies
expectations in the next cycle of inquiry.

3.13: Retrospective analysis
When conducting retrospective analysis, one of the challenges is to work through the longitudinal
data sets generated in the design experiment so the resulting claims are trustworthy. Here, Cobb,
et al. (2003) stress the importance of being clear about the types of criteria and evidence used so
that other researchers will be able to understand and critique the resulting claims. One of the
primary aims is also to place the design experiment in a broader theoretical context to frame it as a
paradigm case of the more encompassing phenomena. One suggestion the authors propose of how
to do this is to contrast the retrospective analysis with the analysis made while the experiment is in
progress. One example given is that of a research group doing an experiment in a classroom where
they intuitively and successfully modify aspects of its instructional design. The retrospective
analysis then attempts to generate a coherent framework that accounts for these effects, hence
making it possible to anticipate outcomes in future designs. Cobb et al. describe the strength of the
methodology as follows:

   In sum, retrospective analysis results in situated accounts of learning that relate learning to the
   means by which it can be supported and organized (....) "what works" is underpinned by a
   concern for "how, when and why" it works, and by a detailed specification of what, exactly, "it"
   is. This intimate relationship between the development of theory and the improvement of
   instructional design for bringing about new forms of learning is a hallmark of the design
   experiment methodology (2003, p. 13).

In his discussion of the strengths of DBR as a methodology, Squire emphasizes its capacity to serve
as a framework for combining and integrating research methods at different phases of research
and design (Squire, 2005). Squire’s second case study illustrates how his DBR studies lead to the development of a different instructional theory for using games in classrooms. Pointing out interesting aspects of the researcher’s role in DBR, Squire writes:

In traditional social science research paradigms, researchers stay as objectively removed from the experiment as possible. Explicitly drawing from the biological sciences, we don’t want to “taint” the research environment, much as one does not want to soil a Petri dish. In DBR, researchers tend to do just the opposite. They tinker with both a design (...) and theory to better match their observations with what they expected to see. This approach may seem unscientific, but I argue that it is more useful than research paradigms which break down classrooms into isolatable variables (2005, p. 13).

Squire argues that what DBR researchers do is to enter an instructional situation, with all its complexity, and experiment by changing the environment and observing until they have a “working” prototype and a more robust theory. These changes should be made in a way that is informed by theory in the hope of gaining better theoretical insights. Squire argues that “the key to good research from this perspective is in clearly articulating learning goals, thoughtfully implementing and tracking changes, and then diligently rethinking experiences so as to generate more powerful theories to guide future work” (2005, p.13).

Cobb et al. also discuss the humble nature of theory generated in DBR as a crosscutting feature of the methodology (Cobb et al., 2003). It is humble because it is domain specific and because it is accountable to the design activity. Different from many other theoretical orientations in education, the theory generated from DBR must “do real work” and provide detailed guidance in organizing instruction. The theoretical aspect is further discussed and developed by diSessa and Cobb in their paper Ontological innovation and the role of theory in design experiments (2004). By addressing the problem that theory is underplayed in design research studies, the authors attempt to characterize a genre of productive design-based theorizing and present the concept of ontological innovations. These types of innovations are explanatory constructs or “new categories in the world that help explain how it works” (diSessa & Cobb, 2004, p. 77). Design is central in this theorizing as it is “the innovation of new scientific categories, specifically categories that do useful work in generating, selecting among and assessing design alternatives” (diSessa & Cobb, 2004, p. 78). Ontological innovations are developed and refined in the process of conducting DBR. Lave and Wenger’s theory of situated learning is used as an example of an ontological innovation developed in other disciplines (Lave & Wenger, 1991).
DiSessa and Cobb describe how it is quite common in design experiments to discover new foci of attention when something new emerges from the design’s context. Design experiments usually encompass extended periods of time and large amounts of activity, much of which is out of focus with the central conjectures. The research team should therefore decide in advance on principles of data selection and yet simultaneously remain open to surprising results and the benefits of completing some data collection beyond the core focus. In their paper, the authors present examples of how surprising observations led to the reorientation of their DBR program on the fly. Video recording every classroom session made this modification of the research focus possible while also allowing the pursuit of issues that arose during the research. The formulation of ontological innovations will thus often lead to the reformulation of instructional goals when working with instructional design. Essentially, however, design research serves as the context for the development of ontological innovations, as diSessa and Cobb note:

> Theoretical work of this type can be demanding in that it involves “building the plane while flying it”. However, the payoff is that conceptual tools are developed in the context in which they are designed to be used, that of developing analysis that can feed back to inform the ongoing instructional design and teaching effort (2004, p. 98)

I will return to the discussion of the levels of DBR analysis in the description of methods used in the study of the game in section 3.2.

### 3.14: Reflections on DBR as a research approach

DBR is described as an emerging paradigm that “can help create and extend knowledge about developing, enacting, and sustaining innovative learning environments” (Design-Based Research Collective, 2003). Being a fairly new research approach, there are fundamental discussions on setting standards for DBR to improve the quality of studies (Dede, 2004; Van den Akker et al., 2006). In his article, *If design-based research is the answer, what is the question?*, Chris Dede addresses the problems involved in the lack of standards and quality in DBR (2004). One of the problems he discusses is that DBR is what he calls “under-conceptualized and over-methodologized”. Dede is critical of the fact that many DBR studies lack a theoretical foundation and do not generate findings for the development of new theory. Earlier, this chapter demonstrated how the discussion of standards for design-theorizing in DBR is central in the community. DiSessa and Cobb suggest the concept of ontological innovations but do not offer many concrete guidelines or standards for building these theoretical innovations. Part of the problem might be that DBR is currently understood as a series of research approaches with a lack of specific guidelines or standards for theoretically approaching different contexts of educational design research. The issue
of what to look for and how, as well as how to decide how to think about these situations of new educational design are central in this regard. I will return to a discussion of this in relation to the study of the game *Homicide* later in this chapter.

The lack of guidelines or standards in these studies of learning ecologies leads to what Dede calls over-methodologized research. Over-methodologized refers to, in this context, studies with a massive excess of data collection and a lack focus where the “elephantine effort resulted in the birth of mouse-like insights in their contribution to educational knowledge” (Dede, 2004, p. 107). Part of the problem in these types of studies, according to Dede, is that the skills of creative designers and researchers do not overlap. The DBR research groups need to deal with both the tension of design interests of “whatever works” and the research interests of theory generation. Over-methodologizing is of course common in other methodologies, but Dede sees the trap of an imbalance between conceptualizing and methodologizing as key to studies of design:

...the trap of too little thought and too much method is one into which DBR can easily fall, believing that large amounts of data enable one to build on the shifting sands of uncontrolled variables, morphing interventions, and changing research strategies (2004, p. 108).

Dede questions the standards for design and the resulting theoretical insights in DBR studies. He asks what standards the community should set for judging what is a design and when a design is too ineffective to be studied. The link between research and design is also questioned: how much theory should guide a design before it can be called DBR? Dede also comments on the absence of clear standards for judging the value of theoretical insights in DBR studies, stating that the DBR community needs grounded ontological discussions on setting standards and the level of quality in DBR research.

As demonstrated in this chapter, the DBR community is trying to deal with a number of dilemmas connected to DBR studies. Studying the learning ecology can lead to over-methodologized studies with massive amounts of unfocused data collection and nearly no new theoretical insights. At the same time, limiting the initial observations of a new design and practice can lead to researchers overlooking or never creating situations allowing them to detect new practices. In studying new educational design, new practices might emerge that we do not know how to look for or where. One solution to this dilemma is perhaps to use methods which open or focus the researcher’s perspective at different times in the study. As described earlier in this chapter, the conjectures made in the design phase can be used to define and frame aspects of study and to select what is to be targeted and what the basis is when studying the learning ecology of a classroom. One
guideline, though, is to approach the first cycle of interventions as grounded in being open to unexpected observations (Strauss & Corbin, 1998). Having established an overview of the practices that emerge when the design is used in an educational context, the researchers are now able to focus the next cycles of design, intervention and analysis on issues of interest. This may lead to conjectures being discarded, a shift in focus or a deepening of the insights the initial design was based on.

This chapter also briefly touches on the role of the DBR researcher. Clearly, obvious pitfalls exist in studying the use of a design the researcher has participated in developing. This problem becomes central if the aim of the result is to validate the success of the design. One possible way to handle this problem is for the research project not to have the same criteria of success as the design process. The researcher should focus on studying the novel practices or categories of existence that emerge when the design enters the educational context; this would provide a greater focus on investigating the users’ constructions or practice as an independent phenomenon removed from the designer’s desire to validate the success of the product developed. The design takes on an independent life in the classroom that can lead to unexpected practices. In other words, I argue that DBR analysis should focus less on how-when-and-what-works-studies of self constructed designs as that type of focus can lead to fairly predictable approaches and conclusions. Part of the objective of creating new educational designs is to create new practices for students. I believe that these practices emerge out of the meeting between the school setting and the new designs and that they may be different from what was expected or what the design was for. As a result, it is essential that the DBR researcher attempts to approach the initial studies of a new design in schools as openly as possible to be able to detect these new practices.

3.2: DBR in the study of Homicide

In the previous section, I summarized and discussed some concrete experiences with conducting DBR in its various phases as well as the main points critics of the research approach make. Many of the discussions in the DBR community seem to concern what methods to add to the DBR framework. In the remainder of this chapter, I take part in this discussion by outlining how I used DBR for designing and studying the learning game Homicide. In Chapter 4, I describe the specific methods I used in this framework, such as the interview and observation methods.

The motivation for using DBR in the development and study of the game Homicide arose from a desire to experiment with integrating research and development in designing learning games. Collaboration between the game industry and academia has been a buzz word in the field for
several years, more so than the norm of practical development. Much of the past generation of edutainment games has been produced in an absence of any coherent theory of learning or underlying body of research (Shaffer, 2007). Most researchers, on the other hand, do not have the skills or experience in designing games that have the dynamics, sets of rules, and narratives modern games contain. Scholars and learning game developers therefore need access to each others expertise. DBR has been described as a methodological approach to generating theory about new learning technology through the development of new types of IT learning materials (Squire, 2005). The motivation for using DBR was the desire to develop more theoretically grounded learning games as well as generate a theoretical understanding of these types of game-based learning environments. The aim was also to develop a greater methodological understanding of using DBR for integrating the development of and research on learning game studies. The following section describes the cycles of the development and research phases in the DBR study of the game Homicide.

3:21: Developing the game Homicide

In this chapter, I attempt to provide an overview of the dynamics in the initial development phase. Instead of going into a detailed description of the game development process, I focus on the methodological insights that created a foundation for further DBR studies of the game. The learning game development project was initiated in 2003 at Learning Lab Denmark. The project was an experiment in bringing innovative learning materials to ‘markets’ - i.e. the focus was on deploying new learning material to schools for further research and development. The goal was to explore the possibilities of developing a learning game that would support working with the scientific method, using a scientific process of inquiry, and yet that would still be an exciting game to play. The aspiration was to make a playful, humorous, yet fairly low budget learning game. Aspects of the crime stories and real-life crime lab genres from television series were combined with computer games and traditional learning-by-doing activities such as role playing and simulation methods. The development team consisted of a core group of people functioning as designers, writers, developers and researchers. A common feature was that everyone had some type of academic theoretical approach to game development, as well as a practical media production background. The team also consisted of other participants on an as needed basis, including actors, consulting teachers and specialized educational researchers.

The development project, which was not initially set up as a DBR project, went through four different developmental phases. The first phase involved building the theoretical foundation and conceptualization. The team started with a knowledge gathering phase that included studying the
content of the game (forensic techniques) and researching situated learning theory (Lave & Wenger, 1991), literary theories, and role-play theories in order to conceptualize the structure of game. In the second development phase, the team produced a pen-and-paper-version of Homicide, which was an alpha-tested product generated based on the players’ use of roles and their level of science learning content. The researcher was an integrated part of the process, working primarily with the science content. Phase three, the final phase of the game development phase, led to the production of a beta version of the game that went through several iterations (related to two interventions in schools) before the game design was finalized. The game designers, researchers and teachers worked together on integrating science learning elements and game elements in the final product. Phase four included dissemination, teacher education and proposals for future studies of the game as a learning environment. The model below illustrates the order of the phases the development project went through.

**Model 3.2:** The ‘osmotic’ model was the product design approach used in the Homicide project. The left circle mimics the traditional way of doing educational research, where the main “customers” are the researchers’ peers. The right circle mimics a normal production cycle, but with a much stronger role played by user feedback. Ideally, a design research project moves in synchronous circular movements, starting from the center and going in both directions; this synchronicity, however, rarely happens in practice (Ejersbo et al., 2008).

This model refers to the process of osmosis, because there is an inherent fluctuation between concentrating on designing and concentrating on theoretical reflections. The osmotic model is not an instruction manual for doing proper research, but merely a simplification of navigating between various aspects of the research process. The arrows are meant to show that there is a sequence or
a chronology - rather than representing phases of a research process necessary for the maturation of a design research project. The model’s starting point is the center or ‘the problem’; and the optimal research process should then be understood as performing iterative and synchronous circular movements in both directions.

The focus of the *Homicide* project was on the development of the game. The initial design of the concept was theory-driven, but the process as a whole lacked a deeper analysis in relation to redesign and theory building. This problem may be rooted in the balancing of the roles of developers and researchers and an issue that is perhaps endemic to DBR projects, especially large development projects like *Homicide*. A team needs to find a common language and cultivate respect for the contributions of each team member’s role while simultaneously accepting certain limitations regarding the level of active commitment in all aspects. For example, it may not be possible for researchers to fully understand and integrate the theory that is the focal point for the material produced without also being an integrated part of the development process. The designer will not be able to make theory-driven designs without being an integrated part of the research, but there might be processes that are meaningless to one party or another. When the game is fine-tuned to work, the developer may find it meaningless to keep changing elements to get a deeper understanding of the learning processes the game facilitates. The researcher, on the other hand, might find it meaningless to keep adjusting technical details that are not important to the research focus. Consequently, one solution could be for the researchers and designers to consider separating certain processes.

### 3.22: Cycles of conducting, analyzing and preparing design experiments

After the game was developed, the DBR study ran through cycles of intervention, analytical work, idea/problem definition and design. In this chapter, I provide an overview of the different stages in the study as well as the level of analytical design work involved in the different phases. The following table is an overview of the classes, hours and periods of observation, as well as the particular stages of the DBR process.
<table>
<thead>
<tr>
<th>DBR Cycle</th>
<th>Class</th>
<th>Hours of observation</th>
<th>Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cycle 1</td>
<td>Class A</td>
<td>25</td>
<td>March 2004</td>
</tr>
<tr>
<td>Cycle 2</td>
<td>Class D</td>
<td>25</td>
<td>December 2005</td>
</tr>
<tr>
<td>Cycle 2</td>
<td>Class C</td>
<td>20</td>
<td>January 2006</td>
</tr>
<tr>
<td>Cycle 3</td>
<td>Class B</td>
<td>25</td>
<td>February 2006</td>
</tr>
</tbody>
</table>

Table 3.1: Overview of observations conducted in classes in this study.

The attempt to categorize the research cycles of problem definition, design, intervention, and analysis should not be seen as a rigid system of independent steps. The boundaries between the phases were blurred. Intervention included redesigning on the fly, and problem definition was part of the design phase. Nevertheless, the study ran through cycles of phases where the focus was primarily on intervention, design or analysis. This chapter should thus be seen as a way of organizing the progression of this extended DBR study. The description of the different stages in the research is based on published papers (Magnussen & Jessen; 2006, Magnussen, 2007a; Magnussen, 2007b), transcriptions of video taped design meetings between the researcher and game developers, transcriptions of evaluations between the researcher and teachers, and a logbook covering the development of the project over the past two years.

**Cycle 1: Conducting and analyzing the first design experiment**

In the final phase of the game development, the researcher and the game development team conducted one initial week-long study of an eighth grade class as they played the beta version of *Homicide*, an almost complete version of the game. In the initial tests of the beta version, the class being studied played the full version of the game run by their science and language teachers. I conducted video observations in all the classes studied to document the investigation practices of each group and to focus on the direct interaction in the pupils’ process of inquiry. A detailed methodological description of the use of the video observations is provided in Chapter 4.

The initial educational goal of the game design was that it should support work with inquiry processes as the basis of scientific investigation. These goals were based on a rather traditional understanding of the inquiry process as a series of steps: problem definition, establishing hypotheses, conducting investigations, making observations, collecting data, analyzing results, and the construction of theories. As a result, we tried to incorporate structures in the game interface and in the work designed for the groups and meetings that would support the student tasks involved in these steps. First, students had to identify the problem (who was murdered and who are the people implicated?) by reading through local police reports. Next, they had to identify what
to investigate to gain enough knowledge to solve the problem and begin carrying out their investigations, i.e. by listening to interviews with suspects and by doing a technical analysis of clues from the crime scene. These activities required looking up information and reading the guidelines in the forensic handbook about how to analyze clues and interviews. After the collection of data, they should then be able to build hypotheses and theories about the case.

The first conjecture in design study was that this structure would support the step-by-step work involved in scientific inquiry. Consequently, in the initial observations done in Class A, I paid special attention to the pupils’ investigation practices at the different stages of the process, focusing on how the first hypothesis about possible suspects and actions in their cases was formulated, what tools and actions they applied in the analysis of the data, and the pupils’ argumentation in formulating a final theory. In spite of this focus, I attempted to approach the studies openly to be able to detect unexpected approaches (Strauss & Corbin, 1998).

The general observation in the class was that the game created an intense situation where the pupils independently organized the inquiry process in groups, created tools for the investigation process and actively discussed problems across groups. Early in this study I became interested in the apparently complex representations the students produced in the initial phase of the game and then used throughout the inquiry process. Apparently, these rather complex representations were central in their inquiry and working process. Many of the discussions in the investigation took place around or with the representations present. Having been part of the development of the game, I did not expect this apparent creativity in production, design and use of representations. The game material, as indicated in Chapter 2, suggests how students can make galleries of suspects, but the representations produced in the first class observed seemed to differ both in content and design compared to the pre-produced example. As a result of the observations made during the first day of play in Class A, I decided to follow the development of the students’ work with representations while still doing observations of other processes in the game such as laboratory work and teacher participation. In these studies, it also became evident that the participating teachers had diverse approaches to the situation. This theme also became a subject of investigation in the later observations.

These first observations of representations produced and used in Class A brought up many unanswered questions for the subsequent analysis: What kick started the idea? When and for what purpose were the representations used for and by whom? What process was connected to them? What supported their further use and development?, and so forth. These questions were the
subject of the papers written in the analytical phase of the first cycle of DBR studies (Magnussen, 2007a; Magnussen & Jessen, 2006). In this analysis I compared student use of representations in Class A to STS descriptions of how representations are used in scientific practice (McGinn & Roth, 1999). The analysis, which overlapped the interventions in Class B, C and D, generated the first local theories of the student use of representations in the inquiry process.

Cycle 2: Conducting and analyzing the second design experiment
In the fall of 2005 and the winter of 2006, I did two weeks of observations and interventions in two different classes (Class C and D). The reason for grouping these design experiments in the same cycle is that there was no analytical phase between the two that influenced conducting the design experiments.

In the initial studies of pupils playing Homicide in Class A, I observed how ideas and the construction of representations developed in and across groups. Methods for solving the puzzles in the game, such as the development of representations, developed in one group and then spread to other ones. This cross-group development of ideas and representations, and how the game-based learning space supported it, was therefore one of the initial points of interest in the next round of observations in Class D. The purpose with these observations was to gain a deeper understanding of the representations and ideas, and how they were redesigned and developed in and across groups in the game-based learning space. One of the conjectures in this case was that the simulation of a professional environment supported the students’ independent approach to the learning situation and the development of representations. I thus focused on documenting the students’ discussions and interactions in relation to the representations as well as their development of the structure and design. I still documented other elements, such as the different levels of student commitment and the different roles the teachers took on in the game. This led to the collection of data and an analysis of contrasting teacher roles in the class and their influence on the learning and playing of the game (Magnussen, 2007b). The paper with the results of the observations on teacher roles is included in the appendix of this thesis.

In Class C, in collaboration with the teacher, I experimented with not providing the students with paper or boards or other materials for making representations. In addition, in the introduction from the teacher at the beginning of the game, the class was not encouraged to hang anything on boards or draw representations in order to see whether they would start producing representations without being encouraged to do so and without having any relevant materials available. The underlying reason for making this design experiment was to gain a deeper understanding of what
made students produce the above-mentioned types of representations. The conditions under which the game took place in the class also provided data for the analysis of this investigation. Because access to the Internet was not available in the school’s science laboratories, the game was set up in the school’s computer room with no specific workspaces with direct access to boards for most of the groups. This setting also provided an overload of computers compared to what was intended in the game design. I decided to go through with this round of observations as the altered conditions in the class could create a contrast to the observations in the other classes. The observation in this class led to the collection of data and an analysis of which elements in the different settings in the classes supported or were an obstacle to the student work with representations. I will return to the description and analysis of these observations in Chapter 8.

**Cycle 3: conducting and analyzing the third design experiment**

In February 2006, I completed the final design experiment and data collection in Class B, a class at the same school as Class C. The group of teachers running the game in this class consisted of some of the same teachers who had run the game in Class C, which means some of the teachers had experience in running the game. As a researcher, I was also more experienced at this stage both in respect to having sharpened my focus on observing the work around representations, but also in respect to working with this specific group of teachers. The close work with this group of excellent open-minded teachers meant that I had the opportunity to carry out both planned and more spontaneous design experiments during the course of the game.

In this class, my focus was primarily on studying student work with representations. In each of the classes I had done observations in so far, I observed students producing representations for similar purposes but with different designs and content. I observed how they designed and used their representations but had not yet conducted a deeper analysis of these practices. As a result, I did not have a clear understanding of student reflections involved in the work with representations. The conjecture at this stage was that students worked with representations but did not reflect on the design or criteria that they were based on and had to fulfill in the investigation. In the final analysis of the collected sets of data, I believe that this assumption partially proved to be wrong. I return to this issue in the analysis of student constructions of representations in Chapter 5. The focus of the final design experiment was partly to see if I could apply changes to the game in the class that could lead to student discussions and reflections on different formats of representations and on their focus in the investigation.
In this study, I have attempted to create ideal conditions around the students’ work by arranging with the teacher to provide them with boards and workspaces in the classrooms. The groups were only granted access to one computer in the computer room, which located separately from the class. They were encouraged to print out the case files to work on them in their workspaces. This setting was chosen after an evaluation done by the researcher and the teachers of the work done in Class C and the limiting conditions in that setting. During this evaluation, I encouraged the teachers in Class B to create workspaces with access to only one computer.

Before the game was run in Class B, I designed, in cooperation with two of the game developers, a change in the intro case to *Homicide*. The intro case is a simple case with few suspects that can be solved in the first two to three hours of playing the game. The case is intended to be an introduction to the students to the game interfaces and the different forensic techniques. As part of this intro case, an introduction about making different types of representations was added. In the beginning of the intro case, the groups were asked to make one of the following four types of presentations:

1) A presentation showing what happened at what time in the case,
2) A presentation providing an overview of their theory and proof of what happened in the case,
3) A presentation providing an overview of the crime scene and what the investigation of clues indicated about what happened,
4) A presentation providing an overview of the characters in the case and what the student data from the investigations proved about the characters and their relationship to the suspect.

At the meeting where this design change was made, a discussion took place about the difficulties in applying this level of reflection to the case. The main problem was that adding a meta-reflection level to the representation work might have the effect of breaking the fiction and consequently make the game meaningless to the students. The idea was therefore to add this change to the gap between the intro case and the main case to avoid interrupting the narratives in the different cases.

Using the word ‘presentations’ instead of representations may have created confusion in the student and teacher group concerning what they were supposed to make. I selected this word in the belief that the, at that time, rather undefined term ‘representations’ would only make sense to
me, the researcher. In terms of developing the design, this experiment was not very successful. Students unenthusiastically made presentations by sticking pictures on poster-size paper. These presentations were not used in the investigation process and only a few groups used them in their presentations. When the main case was initiated the groups initiated an independent process of constructing representations by hanging papers on the display boards around their work spaces which created representational structures radically different from the instructed presentations made in the intro case. The representations made in the course of the main case became central in the students investigation processes in game which will be described in Chapter 6. Though unsuccessful, this experiment provided me with hypotheses on that the complexity of the main case compared to the intro case could be a factor in the initiation of construction of representations. I will return to the discussion of this aspect in Chapter 9.

3.3: Reflections on use of DBR in the study of Homicide

In this chapter I outlined the various phases of the DBR study of Homicide to provide a background for the reader to understand the methodological choices made in the study as well as the background for the analysis in subsequent chapters. The study was carried out with a dual objective: to develop a game to support work with professional scientific inquiry and to use this game to gain theoretical insights into what emerges out of the meeting between this type of game and science education in schools.

In the initial phases of the design of Homicide, the focus was on the development process and less on generating theoretical insights. Intuitive ideas about scientific inquiry process, game design principles and practical experience were more predominant in the phase of designing of this new type of learning material than theoretical knowledge. It is difficult to say anything definite about what the right balance is between theoretical findings, heuristics and empirical analysis as it is highly dependent on the context, but it should be something developers and researchers pay attention to throughout the whole process. Using the osmotic model (Model 3.2), this study illustrates an osmotic pressure where the concentration of energy initially is on the development of a new type of learning material with a pull toward developing theoretical insights in the later phases of the study. The analysis in this study also developed from generating local insights in Class A into how the game supports working with professional scientific inquiry into broader theories of what supports the work across classes. The design process, in contrast, focused initially on developing the game. Later, I used the redesigns of the game to gain theoretical insights into the practices taking place in the environment.
The DBR process in the present study can be viewed as a series of cycles of approaches which progressively became more focused on certain aspects of the settings in the classes or the foreground of the study (representations and teacher roles), hence removing focus from elements of the background of the study. This focus concerned problem definition, redesign, intervention, and analysis.

![Diagram of DBR process](image)

**Model 3.3:** The three cyclic phases in the DBR study of the game *Homicide*. The model illustrates how redesign, intervention, analysis, and problem definition gradually became more focused on experimenting with representational elements in the class settings, narrowing the foreground of the DBR studies. The set of double arrows in the model indicates that simultaneous analytical phases take place throughout the study.

The osmotic model (Model 3.2) shows the design and research phases as being separate in DBR studies, which is perhaps a useful way to look at them regarding the development of commercial products such as the game *Homicide*. This model is less useful in the later phases of design and analysis, where the different stages became integrated depending on the results generated in the other phases. The set of double arrows in the model above indicates that simultaneous analytical phases take place throughout the study. My role in these studies has been to intervene and to observe. In the next chapter, I describe the particular methods used in the different phases of this study.
CHAPTER 4
METODOLOGY

This chapter provides a more detailed description of the methods used at the various stages of the DBR study, including observation, interview, and data coding methods. Chapter 3 initiated a discussion on the role of the researcher in the study that will be continued in this chapter. The method descriptions in this chapter are based on a logbook of the development of the project I kept throughout the study. This chapter ends with a discussion of how the methodological approach has changed as a result of the empirical discoveries made in various phases of the DBR process.

4.1: Observation
In their overall approach, the classroom observations are ethnographic in the sense that I empirically uncover and theoretically interpret the practices the learning game *Homicide* creates in the classroom and its effects. During the study, I used ethnographical methods such as qualitative interviews, and participant and video observations. Applying a DBR approach to this study, however, puts the researcher in a special role that differs in several ways from the classical ethnographical approach. As described in the previous chapter, designs are developed from theoretically grounded conjectures. The researcher hence approaches the observations with these predetermined conjectures in mind. This is different from the traditional more openly defined approach of the ethnographer, where the practices and features of an object ideally should be viewed as unknown (Hastrup, 1989). A trait that the two approaches share is the belief that the researcher is caught in the context and unable to work from an objective position (Hastrup, 2003; Squire, 2005). Taking on the position of being a subjective observer, this thesis is the story of the practices I experienced in the classes studied. The background for this story is the observations I made using methods such as video observations that provided detailed objective information about the actions in the social space. In

Ethnographical methods put a strong emphasis on exploring the nature of social phenomenon rather than setting out to test hypotheses about them (Atkinson & Hammersley, 1998). Studying social learning processes is also central to DBR. As shown in the preceding chapter, these conjectures are described as a means for selecting what is target and background in the complex learning ecology. As discussed in Chapter 3, the dilemma of the researcher is to be able to approach DBR studies openly to be able to detect potential novel practices emerging when the technology becomes situated in the school setting. I have drawn on qualitative research methods such as participant and video observations to permit the theory to materialize from the data in
spite of the predefined conjectures (Strauss & Corbin, 1998). Table 4.1 summarizes the observational methods used in the various classes and DBR cycles.

<table>
<thead>
<tr>
<th>Class</th>
<th>DBR cycle</th>
<th>Hours of video observation during the game</th>
<th>Interview methods</th>
<th>Period of the observations</th>
</tr>
</thead>
</table>
| Class A | Cycle 1 | 20                                         | • Short open interviews with students conducted during the game  
• Semi-structured interviews with the class conducted after the game | March 2004 |
| Class D | Cycle 2 | 25                                         | • Short open interviews with students conducted during the game  
• Semi-structured interviews with the class conducted after the game  
• Semi-structured interview with the teachers after the game | December 2005 |
| Class C | Cycle 2 | 20                                         | • Short open interviews with the students conducted during the game  
• Semi-structured interviews with the class conducted after the game  
• Semi-structured interview with the teachers after the game | January 2006 |
| Class B | Cycle 3 | 25                                         | • Short open interviews with the students conducted during the game  
• Semi-structured interviews with the class conducted after the game  
• Semi-structured interview with two groups after the game. Theme: Criteria for construction and use of representations.  
• Semi-structured interview with the teachers after the game | February 2006 |

Table 4.1: Overview of observational methods used in the different DBR cycles in the different classes

4.11: Participant observation

Field work and participant observations are primary elements in the anthropological method, which is characterized as a scientific practice where anthropologists place themselves amongst the members of the community being studied (Hastrup, 2003). To a greater or lesser extent, the researchers have to immerse themselves in the activities of the people being studied. The aim of this method is to generate understanding of real-world social practices as well as insight into the
underlying concepts and understandings that the people in the communities being studied often are unaware of (Forsythe, 1998).

The present study is based on observations in four classes in Denmark. The details of the setting in the different classes can be found in the introductions in Chapters 5 through 9. I did video observations the entire time during the week the game was played in all four classes and participated in elements of the game planning with the teachers. While the game was being played in the different classes, I did not participate as such by playing the game or by being available as an extra teacher to help the students. I introduced the teachers to the game before it was played in the class which means the teachers knew that I had participated in developing the game. During the week the game was played, they would ask me technical or structural questions concerning the game. The students also knew that I was familiar with the game and on several occasions I was asked for the solutions to the mystery, but refused to acknowledge that I knew anything. In general, I did not take part in guiding the students in conducting their investigations. In the initial studies I tried to follow and video tape as many groups and different processes in the game as possible. This primarily included the discussions taking place at meetings and around tables and boards, but also in the laboratory and the computer room. In the last class that I did observations in (Class B), I focused chiefly on the work concerning representations.

In the game situation I was in both a familiar setting and unknown territory. Having been part of the game development team I was quite familiar with the different elements of the game, and as the study progressed, I had seen them played out on several occasions. In each new class, however, I was in unknown territory with no knowledge about the classroom culture, the group of students involved and (in most of the classes) the group of teachers. Prior to this the study of this dissertation, I had only ever completed a few classroom studies and did not have experience as a teacher so the setting was relatively new and exciting for me. This aspect may have helped me keep an open mind regarding the practices I observed as I did not have a set of pre-defined opinions about what I saw in the classroom. At the same time, my inexperienced approach could have been an obstacle in defining significance in order to guide the focus of observation and data collection.

My primary participation and intervention during the week of game playing was taking part in the planning of activities before and during the game. Before the game I would introduce the teachers to the game. At these meetings I would try and plan for certain conditions or actions during the game. This planning was part of the design experiments carried out in the different classes. An
example of this was in Class B where I planned with the teachers to set up workspaces with boards in the classroom in order to create ideal conditions for the students to work with boards. In this class (as described in Chapter 3), I also arranged with the teacher to change the introductory segment of the game slightly and to hand out papers with descriptions of tasks regarding working with representations. I would also intervene during the game to perhaps change one of the design experiments on the fly or to prevent teachers from making mistakes that would break the fiction. An example of a design experiment done 'on the fly' was the interventions done in Class C. In this class I had initially asked the teacher not to provide students with materials for constructing representations. One group then began drawing a representation on the white board behind their table without the other groups following their lead. I then planned with the teacher that he would provide the class with materials, which did however not change the situation. The role of intervening researcher is different from that of the participating ethnographic researcher but an integral part of DBR.

4.12: Video observation

To observe the developing practices in the setting of classes playing *Homicide*, it was essential to use methods for documentation that would make it possible to document the complex situation in the classroom, to follow the development of selected aspects and, later, to track the progression of the selected aspects. The aspects in focus could be collaborative situations between groups of students or the development of artifacts. I have used video observations as the primary method for documenting the practices taking place when the game was played in the classroom. Apart from the reasons mentioned above, I chose this method in the hope that it would allow me to observe both selected aspects and but also to account for possibly unexpected observations. As described earlier, the dilemma of broadening or narrowing the observational focus is central to DBR.

*Homicide* is a game where part of the work involves walking around to different locations at the school, such as the laboratory and the different groups’ workspaces. Consequently, I used handheld cameras in all the classes so that I was able to follow the students around to these different settings to observe the practices taking place there. I did most of the observations on my own. In Class D I was assisted by a research assistant and in Class B I was assisted for half of the week by one of the game developers who also did video observations. On these occasions, we split the groups between us and observed two groups each, after which we shared the observations at the end of the week.
The camera was filming almost constantly the entire time the game was being played in every class. One exception was the first class, Class A, where I did not film the intro case. The continuous filming involved keeping the camera turned on when talking with teachers during the game. The reason for this was to document the changes the teachers and I implemented while the game was going on or evaluations or comments being made while the game was running. I also videotaped interviews with students and teachers where I used the camera as a sound recording device. I filmed the interaction during the student interviews to document what the students pointed to while we talked. A more detailed account of the interview methods used will be given later in this chapter.

The use of handheld cameras to study groups or follow certain processes in the classroom is a highly selective way of collecting data. The researcher must continuously reflect on the reasons for pointing the camera at one event and not another. Using video observations brings certain advantages and challenges into the research process. Goldman, who addresses these advantages and challenges in *Video representations and the perspectivity framework*, poses a series of questions to the communities of educational researchers using video cameras in their research:

> What do we learn during our investigations while videotaping, editing, and analyzing video that we might not be able to learn without having this media form? Are these rich media artifacts a new way of understanding not only those we study, but also, ourselves as researchers as the camera is pointed in a certain direction taping what the camera-person wants to display about these learning cultures? (Goldman, 2007, p. 5)

Entering into a deeper discussion of these questions is beyond the scope of this project, but I will try to address them in relation to the study done in this project. I used video observations to follow discussions and idea development in and across groups, both during the group work and at meetings with the whole class and their teachers. These discussions could have been documented in field notes. The affordances of using this method had to do with documenting the artifacts the students produced. From the initial opening studies in Class A, I was able to track the development of the representations and later produce reconstructions of these artifacts because of the filmed documentation. By using a method which generated visual documentation, I was able to track the development of the representations as a product of the context. Some of the representations are files systematized on a board or drawings on a white board. It would not have been possible or have made sense to remove these formats from the classroom to analyze them out of context. The affordances made available from using video observations were of course a combination of the media and the choices I made in the specific situations. I systematically filmed the boards and
posters with short intervals throughout the entire week in all four classes. This allowed me to later track the development of the artifacts to connect their development to practices and events in the social space. As described earlier, this method also allowed me to change focus on the fly. Examples of this were in Class D, where I decided to focus on the teacher roles in the class, too (see Appendix for paper on this subject).

Goldman also poses questions regarding the use of video observations in ethnographical studies. Traditionally, ethnographers use field notes as an observational method. The belief held by the ethnographer during field studies was that describing the participation in a community and the practices of this community was not the truth. It was a partial truth, a construction of what was experienced and how the ethnographer contextualized the experience into a narrative. Goldman points out that this understanding and process can be challenged by using video observations. The recorded data can be shared and interpreted by both other researchers and participants, who can take part in the interpretation of the data. Doing so allows for the possibility of bringing new elements into the research phase, but it also poses a challenge to the researcher’s work of choosing between and integrating the many different interpretations (Goldman, 2007). In addition, using video observations compared to field notes adds different modes of interpretation into the observational phase, i.e. the difference between deciding where to point the camera and what to take notes on.

4.2: Interview

Being an exploratory study this thesis takes on several perspectives in investigating the practices enacted in the settings of the play of the game Homicide. The objective has therefore also been to make use of different observational methods which would allow for different perspectives on the studied practices. Apart from observations of the students’ practices and development of the constructed representations it was essential to draw on methods which would allow an insight into the interaction viewed from the players’ perspective. I have therefore conducted various types of research interviews with the students and their teachers. The research interview attempts to reveal and generate an understanding of themes of the research from the perspective of the respondent (Kvale, 1996). The following is an outlining of the various types of interviews done in the study.

I did three types of interviews as part of the study. These interviews had three different purposes and varied in the amount of structure they contained. The last two types of student interviews are described in detail as I have used data from the interviews in the study. The first type of interviews was organized as described in Kvale (1996); semi-structured interviews based on an interview
guide containing an outline of topics to be covered and with suggested questions. The interviews, which lasted 30 minutes, were done in each class immediately after the students had finished playing the game. They concerned general subjects in relation to the game, such as “What did you think about the game?” and “What was different this week compared to a normal school week?” The purpose of these interviews was to obtain an overview of what issues the students viewed as important in relation to playing the game. This type of semi-structured interview concerning general topics was also done with the teachers in the various classes after they had finished playing *Homicide*. My objective with these interviews was to gain a broad picture of how the teachers viewed the game and the participation of the various groups. Apart from the more general questions, the interview guide also contained questions on how practices in the game differed from everyday practices in science classes and if the representational practices observed when *Homicide* was played were part of the curriculum being taught in science and Danish classes. I return to the results of these interviews in Chapter 9.

The second type of interviews, which took place while the students were playing the game, focused on the student inquiry process and their construction of representations and theories, but was not based on pre-defined questions (Kvale, 1996). The interviews were short, typically consisting of only two or three questions, and customarily took place while the students were working with their representations. I would ask questions about this process, such as “Can you explain what you are making?” or, if students were working on several representations, I would ask how one differed from the other. The affordances of this type of interview were that the subject being discussed was a tangible object the students could hold in their hands or be in the process of constructing while we were speaking. On some occasions, this meant that students were able to give detailed explanations about their actions while addressing them, or immediately after they took place instead of after the game. On other occasions, these types of questions seemed less meaningful to students, an issue I will return to below. Overall, this type of interview provided me with detailed descriptions of practices in the first study in Class A, and I therefore continued conducting this type of short interviews in all four classes.

The last type of interview with the students was a fifty-minute videotaped group interview with two of the teams in Class B. A semi-structured interview completed two weeks after the students had finished playing the game, its purpose was to understand why the students constructed and used representations. I was interested in investigating what the criteria were for this format, i.e. what was a good or a poor representation and why. In the previous classes where I had done observations, I had experienced situations where the questions I asked the students about their
work with representations seemed meaningless to them. My interpretation of this was that these tools became such an integrated part of their work that the decisions and thinking processes in the conduction of representational practices became tacit. I was thus looking for an interview technique which could make students view their own practices from another perspective. I discussed this with Professor Andrea diSessa, who was visiting Learning Lab Denmark at that time. He suggested that I should show the students pictures of another class’ representations and ask them to compare them to their own work. Showing the students that work with representations in the game could be done using other formats might allow engaging in a more generalized discussion of the criteria for this type of tool.

Consequently, I designed a semi-structured interview guide where the first part contained topics concerning the structure, use and initial reasons for constructing representations. This part of the interview contained questions such as “Can you explain how this is constructed?” and “How did you come up with the idea to make this?” When asked with the representations the students had constructed during the game at hand, the students answered the questions by pointing to elements of the representations during the detailed descriptions of their constructions. Nevertheless, the overall level of engagement was rather low in this part of the interview. This changed in the second half of the interview, which was structured around topics concerned with comparing the Class A and B representations. Printed pictures of the Class A representations were brought out during the second part of the interview that resulted in a new level of engagement. Students immediately started making comments about the structure of the Class A representations, interrupting each other to express their viewpoints on questions concerning how a certain representation compared to their own. This also led to a long discussion on the criteria used for their own constructions. Situations from this interview are further analyzed in Chapter 8.

4.3: Categorizing and presenting data
As evident from the above descriptions, this study is based on many hours of video observations as well as hours of semi-structured interviewing, making available an extensive amount of data material to organize, code and analyze. Student work with representations was a central focal point of my investigation of practices emerging in the learning-game-in-school environment. On a practical level, organizing and coding the plethora of data was necessary to support a further investigation of these practices.

After the last set of observations in February 2006, I began systematically sifting through the many hours of observations. I decided not to transcribe the data sets on the tapes because I estimated
that doing so would probably take up the remaining time left in the project. While looking at the tapes and listening to the conversations, I wrote down as much of the dialog as possible, while the tape was running, as well as descriptions of the set up in the different situations, including, for example, what the students did, what group it was, etc. I only paused the tape to make extra notes on items that specifically caught my interest. I addressed these notes with questions such as “Why do they do this at this stage in the game?” The overall idea of approaching the data in this manner was to get a broad overview of the elements of practice in the classes. One factor with this procedure was the possibility of overlooking incidences that I would have detected in a transcription. My interest, however, was to detect typical elements of general practice in and across classes rather than pinpointing isolated events, thus this approach was useful for this purpose. Later in the analytical process I of course studied central passages on the tapes in detail.

The next step was organizing the notes on the data, a process inspired by Strauss and Cobin’s method of open coding:

Broadly speaking, during open coding, data are broken down into discrete parts, closely examined, and compared for similarities and differences. Events, happenings, objects, and actions/interactions that are found to be conceptually similar in nature or related in meaning are grouped under more abstract concepts termed "categories". (Strauss & Corbin, 1998, p. 102).

Most of my data included observations of social interaction in the setting the game was played in as this was my primary field of investigation; hence the system used to code the data had to be directed at organizing this type of data. The main theme of investigation established during the observations were ‘representations’. To move on in the investigation of this theme, it was necessary to break down the empery concerning the theme into categories, which led to the definition of the following categories:

<table>
<thead>
<tr>
<th>Theme: Representations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Categories of observations where students:</td>
</tr>
<tr>
<td>- Use representations in discussions</td>
</tr>
<tr>
<td>- Use representations in cross-group work</td>
</tr>
<tr>
<td>- Produce representations</td>
</tr>
<tr>
<td>- Use representations for presenting their case</td>
</tr>
<tr>
<td>- Critique representations</td>
</tr>
<tr>
<td>- Modify representations</td>
</tr>
<tr>
<td>- Design new representations</td>
</tr>
</tbody>
</table>
I also had categories which covered situations in the notes where I during the video observations interviewed or interfered, took close up camera shots to document the development of representations, or commented on the actions in the class, and a theme concerning teacher roles (see Appendix). The categories were established by color coding the data by going through all the notes and assigning situations belonging to each category with a separate color. Events in the category ‘student production of representations’ was thus labeled with a yellow color, etc. At this stage I decided to use observations in Class A, B and C for analyzing the work with representations. The three classes made different types of formats in different types of settings, inspiring the hypothesis that comparing similarities and differences in the dissimilarities in these settings might provide insights into distinct types of practices in learning games. In Class D, as mentioned earlier, I observed different types of teacher roles compared to the other classes. The results of these observations are covered in the paper Teacher roles in Learning Games – When Games Become Situated in Schools (Magnussen, 2007b) in the Appendix of this thesis.

The aim of categorizing the data was to look for similarities and differences in the work done with representations in and across the different classes. After color coding the categorized data by class, I thus compared the categorized data between the classes to look for differences and similarities. All the scenes belonging to a particular category (eg. student use of representations in discussions) were compiled in one file, making it possible to compare the variety of ways of engaging in the same types of actions; i.e. how students in the individual classes used their representations in diverse ways when discussing or constructing them. This led me to ask new types of questions directed at comparing the practices, for example, of “What role does the physical space play in this practice?” or “Do they begin making representations at the same point in all the classes?” This comparison turned out to be valuable for the overall analysis of representational practice in the setting, an issue I return to in chapters five through eight. In the following chapters I focus on presenting and analyzing three perspectives contained in my data: The visual representation and how it changes, the content of the discussion during the work with representations, and students pointing to the representations in their discussions.

4.4 Change of methodological approach

This and the previous chapter presented the methodological approach and observational methods used in the various phases of the DBR process. A description was given of how the initial design of Homicide was inspired by theories of situated learning (Lave & Wenger, 1991) as well as of how the first observations were approached in part from an ethnographic perspective but with a focus on possible situations of inquiry. I observed how students constructed representations which were
central in their presentations of and investigations into the criminal cases in the game. As a result of the first observations, the empirical focus was partially changed and consequently the subsequent DBR interventions also focused on documenting the representational practices. When entering the final analytical phase of the project, I identified a need for a different methodological approach on the background of the change in empirical focus. The focus had changed to include the materiality of the representations and I thus needed to apply a methodological approach which would enable me to understand how this entity was a part of the interaction in the inquiry in the game. As already described in Chapter 1, the theoretical and methodological approach of this thesis is inspired by STS and ANT. The following briefly outlines how ANT inspired the methodological approach applied to the analysis of practices in the various settings of classes playing *Homicide*.

The approach to understanding these situations of practice is inspired by the symmetrical view on human and non-human actors in ANT (Latour, 1987). ANT is often misinterpreted as wanting to attribute non-human actors with the same intrinsic qualities, such as feelings, the ability to learn, etc., as human actors. According to Latour, however, the principle of symmetry has a different meaning:

> ANT is not, I repeat is not, the establishment of some absurd ‘symmetry between humans and non-humans’. To be symmetric, for us, simply means not to impose a priori some spurious asymmetry among human intentional action and a material world of causal relations. (Latour, 2005, p. 76)

The principle of symmetry thus simply states that we should enter the analysis looking for agency while attempting not to make assumptions about the intrinsic qualities of the actors in the given settings. In ANT, this is an attempt to identify action in networks of related actors which, as described by Latour, does not direct us to a certain origin of this action:

> ...the very word actor directs our attention to a complete dislocation of the action, warning us that it is not a coherent, controlled, well-rounded, and clean-edged affair. By definition, action is dislocated. Action is borrowed, distributed, suggested, influenced, dominated, betrayed, translated. If an actor is said to be an actor-network, it is first of all to underline that it represents the major source of uncertainty about the origin of action...

(Latour, 2005, p. 46)
As described in Chapter 1, this is an explorative study and I thus, beside the ANT inspired approach, also focus on individual competences and learning to broaden the understanding of practices enacted in *Homicide*. The ANT inspired approach is, however, used for opening the study to a broad understanding of actors influencing practices and learning in *Homicide* and for considering how and in what networks of related entities representational practices and competences are enacted. I thus enter the situations looking for representational action to identify how the given action is influenced, translated, transformed etc. and to identify what networks of related entities or actors the action is enacted in. On a concrete level this means that the analytical chapters begin with pragmatic descriptions of the settings in which the game took place in the various classes in order to open the study to identifying possible actors in the given settings. As the analysis progresses from Chapter 5 to 9, I extend the study of entities in networks of representational action to the network representational practices are enacted in and the various related entities in these networks.
PART II
REPRESENTATIONAL PRACTICES AND COMPETENCES

The focus in Part II of this thesis is to address the issues in the first half of the research objectives: to understand what practices are established and what competences are enacted when the game Homicide is played in schools. Chapter 3 describes how student constructions and use of representations for inquiry gradually became a focus point in this study. This empirical focus is the vantage point from which I look at enacted practices, competences and learning processes, as well as the network in which they are enacted. Part II is the first part of that analysis. Chapter 5 presents the first studies made of students creating representations for presenting their criminal cases. The focus of this study is to understand practices related to the construction and use of these representations. In Chapter 6, I take the investigation a step further to understand what competences are enacted in the use of representations in inquiry processes.
CHAPTER 5
REPRESENTATIONAL PRACTICE

This chapter presents the initial studies on students constructing representations as part of their investigation practice in the game *Homicide*. The aim is to understand the practices involved in the construction of representations and how students use these representations for presenting their case. This is done by aligning representational practices in the classroom with the epistemology of inscriptions, immutable mobiles and translation for the construction of scientific facts (Latour, 1990). I draw on these concepts in the analysis of representational practices in the first class, Class A. At the end of this chapter, I use the definition of meta-representational competence (diSessa & Sherin, 2000) to initiate a discussion of the nature of the competences students put to use in this work. The data in this chapter is from Class A, the first class I did observations on using the beta version of *Homicide*. As in all of the remaining chapters, I introduce this chapter with a description of the setting in which the game took place.

**Observational setup in Class A**

Class A was an eighth grade class at a public school in Copenhagen with students aged 14 to 15. *Homicide* was conducted for an entire week of school (as intended in the game design), which in Denmark means six hours a day including breaks. The game was run by two experienced teachers, the math teacher and the Danish teacher. Two physics and chemistry teachers provided assistance with the laboratory work. As this was also a beta-test of the game, two or three of the developers were present during the week to solve possible hardware or software breakdowns or flaws in the instructional text.

The group workstations were set up in a school lab room. The class was divided into four groups with four or five students in each group. As described in the game manual, each group had a laptop with the game installed. Each group had a separate base located at the long laboratory table along the walls of the room (see Picture 5.1).
The students thus sat in the same room as the members of the other groups. Apart from the laboratory tables along the walls, the groups shared two large tables in the middle of the room that were used for some of the technical analyses and group discussions. The teachers also used these tables for status meetings. The laboratory work was done in an adjacent school laboratory. The teachers provided the groups with poster-size paper to use in their work which the students hung on the cupboard above their work spaces (see Picture 5.1).

5.1: Representing the case
The first situation described is from the initial status meeting in the groups’ main case. At this stage, the students in each group had finished the intro case and had been given access to the interface with their main case on their group’s laptop. They had had 15 to 20 minutes to look at the files to gain an overview of the case before presenting it to the rest of the class. At the meeting all the students and their teachers sat around a table in the middle of the room in the laboratory where the game was set up. Prior to the situation being described, the students from other groups had presented their cases. Presentations by these groups, interrupted only by the teacher’s questions, were done either by reading from the case files or from notes based on information and interviews in the game files.

Group A1, the main focus in the following situation, began their presentation with one of the boys, Jan, reading a paper the group had written using the details from the autopsy report downloaded from the game interface. After this, another boy, Martin, held up a drawing he and the group had
made and started presenting the case by pointing to the different boxes and lines on the drawing. The captions under the photos below are transcribed dialog from Group A1’s presentation.

**Picture 5.2**
Martin: Okay, we have Niels Andersen here (points to a circle in the center of the diagram bearing the victim’s name (Picture 5.2)), who was killed. And here is … everybody is under suspicion.

**Picture 5.3**
Martin: Flemming Berggren is under suspicion (points with one finger to the circle bearing Flemming Berggren’s name), Morten Møller (points with a second finger to a circle bearing Morten Møller’s name (Picture 5.3)) and Ulla Winther (points with a third finger to the circle bearing Ulla Winther’s name) are the three people who are most under suspicion. (Several students put up their hands.)
Teacher 1: The most under suspicion...
Martin: Yes, and Niels Andersen (points to the circle bearing Niels Andersen’s name) was a pusher (points to a box with the word pusher and has been involved in crime before with his friend Flemming Berggren (points to the circle bearing Flemming Berggren’s name).
Martin: And they probably have - but we don’t know this yet—but they have probably been dealing drugs together because they were convicted in 2001 of dealing drugs (points with two fingers to two smaller boxes with information on the sentencing connected to a box with information on the conviction and to the circles with Flemming and Niels’ names (see Picture 5.4 and Reconstruction 5.1 for a replicate of the representation).

Martin used the drawing as he continued to presenting the group’s data on the case. The next situation is from the last part of the presentation.

Martin: Then, we have Morten Møller (points to the circle bearing Morten Møller’s name). He is the bouncer at Café Gustav (traces the line connecting the circle with a box with ‘bouncer’ written inside (Picture 5.5)).
Picture 5.6
Martin: Niels Andersen often visited Café Gustav, where he probably sold drugs (traces the line from the circle around the late Niels Andersen’s name to a box with the information (Picture 5.6)).

Picture 5.7
Martin: That’s why we figure that the two are somehow related (uses two fingers to point to the box with Morten Møller’s profession and the larger square bearing information about Niels’ comings and goings at Café Gustav (Picture 5.7) before he brings his fingers together to point at the double line between the two squares).
Martin: This is the only way we can connect them (points once more with two fingers at the two boxes and the lines between them (Picture 5.8)). Morten Møller (points to his name) was employed by Ole Vestergaard (traces the line connecting the two names and points to a circle bearing the name Ole Vestergaard), who was the late Adam Krogh’s colleague (points to Adam’s name in a square at the edge of the diagram). And Morten Møller was also a member of the Melved Amateur Drinkers’ Club (points laughingly at the square connected to the circle bearing Morten Møller’s name), but that probably doesn’t mean anything.

Teacher 1: That was a nice and clear drawing Martin. It can be exemplified and reduced in size, but it was an impressive drawing. It reminds me of the sociometric patterns we use in sociology. But it was good Martin.

Teacher 2: (laughs when Teacher 1 makes the connection to sociometric patterns) Yes, Morten (points to a boy in another group)?

Martin: And his sister was Anna Tomballe (points to a circle with Anna’s name that is connected to the circle with Morten’s name (Picture 5.9)). That’s more or less what we’ve come up with.

Teacher 1: That was a nice and clear drawing Martin. It can be exemplified and reduced in size, but it was an impressive drawing. It reminds me of the sociometric patterns we use in sociology. But it was good Martin.

Teacher 2: (laughs when Teacher 1 makes the connection to sociometric patterns) Yes, Morten (points to a boy in another group)?
Morten: Nothing.
Teacher 2: Yes, that was a nice presentation.
Teacher 1: Martin, two or three colors would help, when you have so much up there.
Martin: I only had two.
Teacher 2: All right, listen up. When you go into a meeting like this, you have to be prepared. I know there were delays (points to another group), because you didn’t get your case file right away. But, this is basically how we expect you to be prepared – with something similar to how Martin and his group did it (points to the group who just finished their presentation).
(Video observations Class A, day 1)
What happened at the meeting? Martin and Group A1 had produced a diagram that they used to present their case at the first status meeting of the game. Present in this situation were the members of the group and the rest of the students in the class, all of whom were seated around a large table in the laboratory where the work stations were set up. Three teachers were also standing or sitting around the table, and the researcher was filming the situation from the other
end of the table. In the background, leaning against walls or withdrawn from the table, were the three game developers who were observing the run through of the first complete version of the game. At this stage, the class had been through the intro case, which I did not record. In this situation, none of the other groups had produced representations for presenting their case, and the use of representations for presenting the case seemed new to the teachers. This indicates that the class had not been encouraged to produce this kind of tool before this situation. In an attempt to understand what the representation was used for at this stage, I examine the structure first. Second, I look at how it was used at the meeting with the class.

The above Reconstruction of the diagram shows that it has several functions. First, it seems to be used to categorize data. The names of every character in the case are circled, and all the other information is written in a box. The system, however, does not seem to be entirely consistent as the information about Flemming Berggren’s violent nature is also circled. The system also seem to have a reducing or focusing function because it centers on illustrating data on the characters’ social activities. Far from all the information available in the characters’ profile sheets appear on the diagram (see example of profile in Picture 2.4 in Chapter 2). Neither physical data about the characters nor data from the crime scene are included. The diagram solely contains information about the characters social activities and relations, i.e. their relation to the deceased, profession or occupation, convictions, club memberships and the interrelation between the different kinds of information. Boxes with related characters’ names are connected with arrows that either point directly at an item or go through boxes with information that concerns both characters. For example, the box that says “conviction for drug dealing in 2001” connects to Niels Andersen and Flemming Berggren’s names as well as boxes with the penalties. This creates a complex system that visualizes the network in Flemming and Niels’ relationship and their collaborative actions.

At the presentation, Martin began by describing the victim Niels Andersen and information concerning this character. Martin then moved outward in the diagram, pointing at arrows and boxes with the names of his closest relations and information concerning them. Almost all of the arrows point from the circle in the center with victim Niels Andersen’s name and outward towards boxes containing other characters’ names or information. This and the central position of Niels Andersen’s name indicate that the focus of the representation is how the victim, due to different types of actions, is related to the other characters. The system is a representation of the victim’s network of relations, which includes characters and data connected to these characters. At two points, however, the representation has more information than what was available in the game material at this stage of the status meeting. As is apparent from the data above, the group did not
find information in the game material about a possible relation between Morten Møller and Niels Andersen. The Reconstruction shows, however, that there is a double arrow between the box with information about Morten Møller’s job at Café Gustav and the box with the following information about Niels Andersen: “Came to Café Gustav often, probably sold drugs here”. Martin explained the double arrow as follows:

Martin: Niels Andersen often went to Gustav, where he most likely sold drugs (traces the line from the circle around the late Niels Andersen’s name to a box with the information (see Picture 5.6). That’s why we figure that the two are somehow related (uses two fingers to point to the box with Morten Møller’s profession and the larger square bearing information about Niels’ comings and goings at Café Gustav (see Picture 5.7) before he puts his fingers together to point at the double line between the two squares). This is the only way we can connect them (points once more with two fingers at the two boxes and the lines between them (see Picture 5.8))

Reconstruction 5.1 shows that the group also included a box with information that Flemming Berggren and Niels Andersen were dealing drugs together. Martin explains the content of the box as follows:

Martin: And they probably have - but we don’t know this yet—but they have probably been dealing drugs together because they were convicted in 2001 of dealing drugs (points with two fingers to two smaller boxes with information on the sentencing connected to a box with information on the conviction and to the circles with Flemming and Niels’ names (see Picture 5.4 or Reconstruction 5.1).

These examples indicate that the representations are used to construct and map theories \(^3\) about relations between characters. In this case, the representation becomes a visualization of the hypotheses they are beginning to construct about the characters in their case.

The question is then how the representation was used at the meeting. Martin presented the case and the characters by pointing to the different parts of the drawing illustrating the relations or characters he was talking about. He did this both when he talked about the information in the diagram that the students retrieved from the game files, and to present the group’s hypotheses about possible relations. During the presentation, the representation ended directing the path of Martin’s presentation as he went systematically though it, methodically reading everything from the center and outward.

\(^3\) Here I use Dianne Kuhn’s definition of “theory” as “what makes sense to me” as opposed to “evidence” which is defined as “sources of knowing” (Kuhn, 2005).
Latour’s theories of the construction of scientific facts offer a perspective for understanding the use of student representations. In, *Drawing things together*, Latour reflects on how inscriptions are used to show or prove claims in scientific practice:

What is so important in the images and in the inscriptions scientists and engineers are busy obtaining, drawing, inspecting, calculating, and discussing? It is, first of all, the unique advantage they give in the rhetorical or polemical situation. “You doubt what I say? I’ll show you.” And without moving more than a few inches, I unfold in front of your eyes figures, diagrams, plates, texts, silhouettes, and then and there present things that are far away and with which some sort of two-way connection has now been established. I do not think the importance of this simple mechanism can be overestimated.

(Latour, 1990, p. 35 - 36)

Latour argues that this use of inscriptions is central in constructing scientific proofs in Western scientific culture. In a dispute between two parties each constructing their own statement, the one who is able to recruit the largest number of allies wins the dispute. The use of inscriptions, or what Latour defines as “immutable mobiles”, is central in this regard. To illustrate the use of immutable mobiles, Latour gives an example of a traveler who wants to document that a certain island is an island and not part of the mainland. The natives on the island draw him a map in the sand on the beach that shows he is in fact on an island. The traveler writes down the map in his notebook and is now able to bring it home to use it in disputes about the geography of the area he visited. He has turned the map into an immutable mobile, an object which can move or be moved without changing shape. It is presentable, readable and combinable with other immutable mobiles. Inscriptions or immutable mobiles can be compared to each other or to other versions of the immutable mobile. The traveler can take home the map of the island and compare it to other maps or descriptions of the area. If these inscriptions support the geographical fact he is trying to construct, the maps become chains of strong allies to be used in disputes to recruit other allies to support his theory. The traveler has invented an immutable mobile which can be used in the recruitment of allies: “You doubt it is an island? I will show you”; without moving more than a few inches, the traveler unfolds the map and presents the geography of the distant island (Latour, 1990). A two-way connection has been established between the island and the map: a distant, complex object has been displaced by a map.

How does this compare to the use of representations in Class A? Using the representation in the presentation clearly changed the situation around the table. The previous group’s presentation
consisted of reading notes based on information in the files of the game material and the teacher asking several questions to their cases. After Martin introduced the diagram, several students raised their hands and the teachers did not pose questions about the work. After the presentation, both teachers praised the representation, and Teacher 2 even encouraged the other groups “to be prepared in the same sort of way – maybe in the way Martin and his group was”. What was it about the representation and the way it was used that could explain this change? Other groups had brought notes and texts to the meeting to present their cases, so it was not only a matter of the text element itself.

By using the representation for presenting the case, Martin was able to bring the case to the meeting in a format that made it visual to students and the teachers. During the presentation, he was able to represent nonexistent fictive characters by pointing to boxes with names and say, “We have Niels Andersen here”. Without moving his fingers more than a few centimeters, he was able to visualize hypotheses about related events by pointing to connected boxes with information on sentences and convictions of the prime suspects. The representation helped him materialize the many fictive characters and the network of relations between them as well as the data on events and actions which could be important for determining their role in the crime. Applying Latour’s perspective, the group established a two-way connection between the complex disorganized case with many types of data and a two-dimensional organized representation of the network of relations.

Using the representation as a displacement of the pile of case files helped the group recruit a very strong group of allies – the teachers. This group of allies then helped the students promote the idea of using representations for presenting cases. As the next section will show, the rest of the groups in the class started to make similar representations after the meeting. So, although it might not have been the central aim of the group, they set the standard for using representations for inquiry and presentation in the class. They were also recognized by the teachers as the group with the best presentation, and thus won the recognition of the authorities both in the game and school context. The representation on the poster had a mobile format that allowed it to be carried around the laboratory without changing shape: it had become an immutable mobile. The students not only brought their posters to the status meetings to present their case and theories, but they also carried them to other groups’ workstations to discuss and compare cases and theories (see Picture 5.9).
But why, in the first place, were the teachers willing to let themselves be recruited? Why did they become impressed with the representation? One possible answer in line with what has already been said is that they praised the work the students had already done compared to the other groups. The students had independently taken data from the game files and transformed them into a format that represented the focus of their inquiry.

5.2: The process of translation

In this section, I focus on the students’ construction process in making the representations. First, I present a situation with another group in Class A, Group A2, and their construction of a representation. The situation for Group A2, who produced a representation after the first status meeting, involves two group members, Morten and Kristina. Their murder case was about the murder of a girl named Marie Johansen. In the situation transcribed below, Morten and Kristina were making a drawing using information from the printed profiles of the suspects available in the online game material. The profiles contain a Picture of the character and information such as profession, weight, height, relation to the deceased and earlier convictions if any (see example in Picture 2.4 in Chapter 2). Morten was looking through the printed profiles while Kristina was drawing the diagram on poster-size paper. In the background, two girls from the same group were taking notes from the videotaped interrogations with suspects. Another boy followed the discussion between Morten and Kristina.

Kristina: Should I write ‘Was promoted before she died’?
Morten: No, no you shouldn’t. We’re just looking at personal relations for now.
Kristina: So, should I write about criminal records and that kind of thing?
Morten: (leafs through papers with printed profiles from the game) We could start with a few of the characters and then attach the criminal records later, if they have one. 
Kristina: Yes, let’s put a green circle around the verdicts.

Picture 5.10
(Morten rummages some more in the pile and stops at a profile (Picture 5.10)).
Kristina: May I have a look?
Morten: It’s nothing much, nothing much. There’s nothing, really.
Kristina: Can I see!? 
(Kristina takes the profile of the brother-in-law of the deceased, a Mr. Poul Berg and reads it.)

Picture 5.11
Morten: And her brother-in-law is...
Kristina: Yes, that’s in here too (points to a box in the drawing in front of her with Poul Berg’s name written in (Picture 5.11)). I have just marked him down as her husband (traces a line between a box with Poul Berg’s name and a box with his wife’s, Anne Berg, name) and... we can write that here, too. What did the other group (points in the direction of one of the other groups) have on this guy Peter Berg (points to a box with Peter Berg’s name)?
Morten: (glances at the group Kristina indicated and gets up) I’ll take a look at him. I think that was in David’s (a pupil in another group) case (Mikkel goes over to David’s group).
Kristina: Yes, yes, all right, but did he do anything?
(Morten comes back from David’s group’s workspace.)
Kristina: Here. Morten, should we add his previous sentence to this one? Morten? (Kristina points to a box with the name Jens Kaspersen written in) He got caught for drunken driving; we should put that in there (picks up a marker with a different color).
Morten: Well, yes, you can do that. So, all the verdicts get a circle like that.
Kristina: Yep, I’ll mark them with the purple one (lifts up her marker).
Morten: Yes, as long as they get a circle, too.

Picture 5.12
Kristina: Yes, yes (Kristina draws a line from the box with the victim’s ex-boyfriend’s name, Jens Kaspersen, and connects a circle to the line (See Picture 5.12 and Reconstruction 5.2 below).

(Video observations Class A, day 1)

The above Picture shows the diagram at this stage in the process. The students drew green boxes with the names of the characters in their case and their relation to the deceased first (parents, sister, etc.).
These boxes were connected with lines depending on who the characters had relations to. At this stage, Kristina had just started including information on the characters that had earlier convictions by connecting these characters’ names to purple circles with a description of the conviction. Picture 5.12 also shows the printed files Kristina and Morten are using for constructing the representation. At the bottom of the Picture is a suggested template for making a gallery of characters which is available in the game material. Above the representation is one of the profiles printed out from the game.

The same day later in the process, Morten and Kristina explained to Teacher 1 what the different colors and shapes of boxes stood for in the representation. At this stage, the diagram had been extended with different colored boxes and circles containing different types of information (see Picture 5.14 below and Reconstruction 5.2).
**Picture 5.14:** The Group A2 diagram at the stage where the group discussed it with the teacher.

**Reconstruction 5.2:** Reconstruction of the Group A2 representation at this stage in the process. Color codes and definitions of these, shapes of boxes, lines and wording are copied from the original representation. The wording of definitions of color coding is also the students.
The blue circles and boxes were defined by Kristina as the characters’ wishes or dreams. Morten added that the blue box also contained information about memberships. The teacher added that the blue circles also could be defined as containing information to do with the characters’ possible motives for killing the victim. This definition was later included in the representation (see Reconstruction 5.2).

What was the overall objective of this work? The group was possibly trying to achieve what Group A1 had achieved, which was to get an overview of the case by mapping relations. They had just seen Martin’s group make this kind of representation and the teachers’ recommended it as a way to prepare for the status meetings. Consequently, they were possibly also trying to achieve the teachers’ recognition by preparing in the manner they had been told to. Kristina and Morten used the same system of boxes and lines as Group A1 and included the teachers’ recommendations on color coding the different types of information. This indicates that the teachers and Group A1 were actors who influenced the construction process. So, were they simply following orders and copying the work of the other group?

There are several aspects that indicate that the work of Group A2 can not just be decribed in this way. First, their work process had a well-established focus. In the situation, it becomes evident that they had a clear definition of what data they wanted to include and map in the drawing, i.e. personal relations. This focus was not expressed by the teacher or Group A2 at the meeting, which means the process of establishing this focus or interpreting that this was the focus took place outside the meeting. There is also a different focus if we compare the structures of the two representations (see Reconstructions 5.1 and 5.2). As described earlier, the A1 representation is a representation of the victims’ network; the victim’s name is central to the representation with arrows pointing from the center to the characters he is related to, to information about him, and to information that relates to both him and another character. In contrast, the box with the victim’s name on representation A2 is not as centrally placed on the drawing as it is on the A1 representation. The A2 group did not use arrows pointing outwards from this box either. The relations do not point from the victim and out. Instead, their representation becomes a map of relations between all the characters with no defining center.

Information about the characters’ roles in the case is also included in the box with the characters’ names instead of in a separate box. This can be viewed as a reduction of complexity of the representation which also becomes visual in the reduced number of boxes and lines. The group
included a new type of information in the blue circles that was initially defined by the students as the characters’ wishes or dreams. After discussing the representation with the teacher, the information in the blue circles was defined as motives and included in the representations. One could argue that it is the graphical alignment of the blue circles that establishes the information about motive in the representation. By being able to compare the wishes and accomplishments of the two characters, the fact that Jens Kaspersen wanted a promotion that Marie Johansen got is revealed, thus also exposing a possible motive for killing her. Overall, the A2 representation is in several ways a further development of the A1 representation with a reduction of complexity and the inclusion of new types of information.

The ANT concept of ‘translation’ and its relation to work with inscriptions in professional science practice is one perspective with which to look at the construction processes in Group A2. The concept of translation plays a central role in classic ANT and is defined as the process of making two entities that are not the same equivalent (Law, 1999). Translation is also used to describe the process in which an actor gains strength by building relations to other actors and by speaking on behalf of other actors. Returning to the example with the traveler and the map described in the first half of this chapter, the aspect of the process now in question is when the traveler makes the two-way connection between the island and the map. By writing down the map of the island and using it in disputes about the geography of the area, the paper with the map and the island become equivalent. But the map can also be seen as an actor that speaks on behalf of the island by gaining strength from its relation to the traveler. Latour, who also defines translation in terms of the interests of fact-builders, writes: “I will call translation the interpretation given by the fact-builders of their interests and that of the people they enroll” (Latour, 1987, p. 108).

In the construction process, Morten focused on visualizing the relations of the characters. In the process of constructing the representation, the students used the diverse kinds of data from the character profiles first and translated them into a network of equivalent boxes with information solely about relations between characters. Kristel focused on earlier convictions as well as the data on wishes and dreams, which later were categorized as motives. In this process, the drawing became a joint interpretation of the criminal case. In this interpretation the case is the characters, how they are related, and what wishes/motives and memberships they have. The process of translation became the process of relating the various actors in the game fiction. Data on clues found at the crime scene are, for instance, missing from this drawing. Group A2 was now able to use the representation (along the same lines as Group A1) to materialize – or speak on behalf of - their interpretation of the case, as well as to enroll allies to support this interpretation of how to
represent the case. The group used the representation at the next status meeting to present their case, and it was central in their discussions during the investigation process, as will be shown in Chapter 7.

Comparing the representation to the definition of network as interrelated entities – or actors - (Callon, 1986), the argument can be made that the representation itself becomes a network of relations. In the network of related characters, a network of purple boxes with information about convictions, possible motives and memberships is also connected to them. In constructing a network with these two types of data, the students constructed an analytical tool that visualizes whether different types of data point to the same conclusion in the investigation. Jens Kaspersen’s motive was more than just being a jealous ex-boyfriend; he also envied the victim’s professional success. This format thus visually provides modes for comparing the success of Marie Johansen and the unmet desires of Jens Kaspersen, allowing the deduction of a possible motive for murder.

5.3: The epistemology of representational practice

Thus far, Chapter 5 focuses on investigating students’ representational practices using the STS lens of inscriptive scientific practice. In this section I attempt to take the investigation a step further and enter the discussion of what skills or competences are enacted in these representational practices. STS and ANT provided a framework for understanding practice in networks of actors, but not directly competences, skills or learning. In the final section of Chapter 5 I discuss possible theoretical perspectives for investigating professional skills enacted in a game/school context.

In his book, *How computer games help children learn*, David Shaffer talks about what it means to think within a subject or discipline (Shaffer, 2007). As described in Chapter 1, he defines the epistemology of a discipline as a particular way of “thinking about or justifying actions, of structuring valid claims” (Shaffer, 2007, p. 32). Epistemology is thus specific to a particular domain of knowledge. Professionals from different disciplines use different rules in structuring their arguments and deciding whether something is true. Arguing that school does not teach students to use what he defines as the epistemic frame of a discipline, Shaffer writes, “The work of creative professionals is organized around what I call epistemic frames: collections of skills, knowledge, identities, values and epistemology that professionals use to think in innovative ways” (2007, p. 12). With reference to frame analysis (Goffman, 1974), Shaffer suggests that being a professional means interpreting ongoing activities through a particular kind of frame. He compares the epistemic frame for a profession to a pair of glasses that color the world in a certain way and that enhance some aspects more than others. The epistemic frame is the combination of values,
knowledge, skills, epistemology and identity people have within a profession. Taking this definition a step further and applying it to a certain class of games - epistemic games - Shaffer writes:

An epistemic game is a game that deliberately creates the epistemic frame of a socially valued community by re-creating the process by which individuals develop the skills, knowledge, identities, values and epistemology of that community.

(Shaffer, 2007, p. 164)

Shaffer argues that epistemic frames are a level of description that includes views on individual and community-based thinking and learning processes (Lave & Wenger, 1991). To become a member of a community individuals have to learn what members of the community know and care about and learn “to decide, explain, and justify decisions and actions according to the norms of that community” (Shaffer 2007, p. 161). Drawing on the concept of epistemic frames, an understanding must be had of how individuals learn to solve problems in relation to the participation in the community.

Homicide is meant to simulate the process of professional criminal investigation. It is designed to more generally support learning about the epistemology of professionals doing inquiry. The attempt has thus been to simulate a specific professional context to support the acquisition of general inquiry skills. The game thus differs from Shaffer’s definition of epistemic games as it does not directly seek to simulate the apprentice situation by “re-creating the process by which individuals develop the skills, knowledge, identities, values and epistemology of that community” (Shaffer, 2007, p. 164). In Homicide, students are placed in the role of the experienced forensic investigator responsible for solving the crime and having to report to the chief of investigations (the teacher). The epistemology of the experienced investigators is that they have to be able to document technical proof for every claim they make, or every theory they come up with. Without proof, claims are of no value. All aspects of the practice in the game are valued according to this, i.e. technical analyses and laboratory tests have to be made thoroughly to give a clear indication of what hypothesis they point to in the context of the case. The primary goal of the game is thus not for students to learn forensic skills as such, but more generally to develop the competences required for doing inquiries by developing evidence-based hypotheses and theories.

This chapter shows how students as part of their representational practice develop hypotheses based on the first analysis of the facts of the case. How do we enter a discussion of the competences enacted in these representational practices? So far I have approached the analysis of representational practices in Class A by aligning them with the epistemologies of inscriptional
practices in science as defined by STS. It has become evident, however, that elements of both the simulated profession in the game and school related elements are influencing the representational practices. In the situation with Group A2 we saw how the character gallery template from the game material was part of the files Group A2 had on the table while constructing their representation. Apart from this possible inspiration from the game material, it is likely that the students were inspired by TV documentaries on criminal investigation as well as fictional series such as *CSI*. The use of character galleries for conducting investigations in these series is a likely inspiration for the students’ representational practice in classes playing *Homicide*.

This chapter, however, also demonstrates how students invented representations fundamentally different from the template in the game material as well as how they independently translated case data into a representational structure. A comparison of the Group A1 representation in 5.1 and Picture 2.3 in Chapter 2 to the template shows that the two differ in key ways. The template suggests that the students print and group character profiles into three groups: suspects, non-suspects, and victim. All results generated are categorized according to this system. Contrary to this, students in Class A focused on visualizing the network of relations and activities amongst characters and not on categorizing characters into suspects and non-suspects. How other students defined the design and method and the teacher’s recognition of the representational investigation strategy also proved to influence the representational practices in Group A2. Consequently, I argue that when attempting to define what competences are enacted in the game/school context and what network these competences are enacted in, it is necessary to apply perspectives that will help us understand these competences in terms of both the professional inquiry practice the game was designed to support and the school context the game took place in. In this last section of Chapter 5, I suggest theoretical perspectives for looking at competences enacted in Class A. In Chapter 9, I follow up on the discussion of what actors influence the representational activities in the network in which competences are enacted.

Chapter 5 has presented how the students’ inscriptive practices align with inscriptive practices as defined by STS. Students use the visual format of representations to materialize their understanding of the case and hypotheses and successfully recruit the teachers as strong allies to support their version. The representation becomes an immutable mobile in the sense that it maintains a shape that allows students to bring it to meetings or to the workspaces of other groups to compare cases. I also showed how students translate data into representations that represent their interpretation of their interests or understanding of the case, i.e. how people and data are related. This translation process allows the representation to speak on behalf of the case.
The students’ use of representations, however, also differs in central ways from the role of immutable mobiles in scientific practice. As described earlier in this chapter, the representations are used to materialize the network of characters but also possible hypotheses presented with statements such as “...we don’t know this yet...” The materialization of characters and their relation to the victim are also used to present the open state of the case at the first meeting, where Martin initiates his presentation by saying, “...everybody is under suspicion...” This use is centrally different from Latour’s description of how immutable mobiles are used in scientific disputes. In Class A the representations are not referred to as proofs of theories with statements such as “You doubt what I say? I’ll show you” (Latour, 1990, p. 35 - 36). The students’ approach in the presentations is open, inclusive and investigative - not conclusive. Looking at the success of Group A1 shows that it is not a result of a successful construction and the proving of facts. After the presentation, the case is still open and has many suspects. What they succeed in passing on to other groups in the class can better be characterized as a method or strategy for investigating the case. Their success is thus due to proving the representational method or strategy for presenting their case and doing investigations. The structure of the game, designed for groups to have different cases with different plots and characters, plays a role in this. Established facts in one case are thus not of direct relevance to another group. As demonstrated, this method is also not immutable but adaptable to changing translational focuses. The classic ANT focus on power structures is thus only partially useful in understanding the students’ use of representations in the game. When studying this method or strategy, additional perspectives must be added to the analytical approach.

In their paper *Preparing students for competent scientific practice: Implications of recent research in science and technology studies* Michelle K. McGinn and Wolf-Michel Roth offer a less power-focused description of the role of representations (McGinn & Roth, 1999). They argue that STS provide a new view of what ‘authentic science’ is that should have implications for how science is taught. Visual representations such as graphs, x-ray images, maps, models, diagrams and hybrids of these are central in creating and communicating science. Scientists create initial representations that undergo transformations in the process of making sense of a phenomenon to themselves and later to others in scientific publications. They describe how representations serve at least three functions in scientific work: as inscriptions, conscription devices, and boundary objects. As inscriptions, representations constitute the phenomenon of interest. Visual representations “provide pictorial or graphical inscriptions of important aspects of the phenomenon under investigation” (1999, p. 21). The visual representation makes the object readable, presentable, moveable and combinable with other inscriptions. Visual representations also serve as conscription devices,
providing focused attention and conversation. Scientists and engineers’ discussions are often about and in the presence of these inscriptions. Last, visual representations also act as boundary objects that coordinate work across groups, time and space. McGinn and Roth give the example of engineers’ design drawings of an airplane that coordinate work at various sites between engineers, welders, business managers, etc. McGinn and Roth argue that this type of representational practice that is a central part of professional science should also be central in science education. Suggesting that classroom environments should be organized to allow students to collaborate on constructing visual representations which should serve as a means for communication in the community, McGinn and Roth write: “Within these environments, students would be expected to use visual representations as integral aspects of arguments, and to adapt and transform their representations to make more convincing arguments” (McGinn & Roth, 1999, p. 21). As an example of this, McGinn and Roth suggest that students could be expected to transform their representations to make more convincing arguments, for example, by graphing data from a physics experiment as a means of defending their findings.

Andrea diSessa and Bruce Sherin present a broad definition of the competences involved in representational science practice (2000). They use the term meta-representational competences (MRC) to describe the full range of capabilities students have for constructing and understanding scientific representations. MRC includes the ability to “select, produce and productively use representations but also the abilities to critique and modify representations and even to design completely new representations” (diSessa & Sherin, 2000, p. 386). DiSessa and Sherin distance their approach from prior studies on representations on mathematics and science that have had a narrow focus on how students produce and interpret a few kinds of instructed scientific representations such as graphs and tables. Thus, they use the meta term to mark the broader perspective compared to these prior studies, and the term ‘representational competences’ to describe the range of activities involving representations in their studies. The orientation in studies of MCR is also different from prior studies which have been focused on how intuitive ideas can lead to misconceptions in science and mathematics teaching. Contrary to this, diSessa and Sherin view the intuitive ideas that students bring into science courses as the resources out of which expertise is constructed.

DiSessa and Sherin have done a series of broad studies on what students know about scientific representations, and what is possible for them to learn. An example of these studies is an experiment done with a class of sixth grade students engaging in designing their own representations of motion (diSessa et al., 1991). In these studies, the researchers describe how
students, over five days, produced a range of effective representations. They describe how they, as part of this development process, argued about the advantages and disadvantages of these representations, and invented their own version of graphing speed vs. time as a way of thinking about and depicting motion (diSessa, 2000). Reporting on how this experiment has been repeated several times, and how the results led to surprising conclusions on children’s understanding of representations, diSessa and Sherin write:

The single most important result of our research on MRC is that students do, in fact, have a deep, rich, and generative (if intuitive and sometimes limited) understanding of representation. (...) Although we were disposed toward this conclusion, we have found that even our own early speculations dramatically underestimated how much students know about representation, and how much of this appears to exist before and independent of instruction. (diSessa & Sherin, 2000, p. 387)

DiSessa and Sherin outline some of the reasons for teaching MRC that are plausible and valuable. They state that letting students develop representations allows them to do and learn about what scientists do. They point out that science and mathematics have evolved by refining and accumulating representational forms. Letting students do MCR-based tasks might also open up science teaching to a group of students who are not otherwise very attracted to the sciences. The classic focus on right and wrong in science might fade into the background in favor of innovation, creativity, and contextual judgment (diSessa & Sherin, 2000).

How do MRC and McGinn and Roth’s description of the scientific use of representations align with my studies of students’ representational practices in Class A? This chapter has shown how representations produced during the *Homicide* project are used as inscriptions by constituting the phenomena of interest (the case), and by making it presentable and movable. They also serve as conscription devices by providing a focus of attention and for discussing the case. Moreover, they act as boundary objects as the representation makes it possible to carry their case to meetings and other groups’ workspaces to compare data and results across groups. We also see, as diSessa and Sherin describe, how students invent and reinvent representational formats. I return to this aspect in Chapters 6 and 7, where the representational formats of another class, Class B, are presented.

The students’ practices, however, also differ in central ways from the representational practices defined in the above research. Content-wise, the students in Class A do not produce what the authors above exemplify as scientific representations. The representations in Class A mainly consist of data concerning the characters personal relations and information about verdicts. Chapters 6
and 7 show how technical and scientific data are included in the representations in other classes, and later in the game in Class A. Nevertheless, we have representations which have a cross-disciplinary content. Another difference is the nature of what is being represented. As described, students do not use representations to prove findings but to represent a developing case. The phenomena which are being described in the MCR research cases mentioned above are well-defined objects, their meaning unlikely to change radically in the same sense as the meaning of an uninvestigated case might. Motion is an established phenomenon in physics which can be represented from different perspectives and with different means, for example, a car that starts, stops or accelerates. The established nature of the phenomenon, however, is known at the initiation of the investigation. The uninvestigated case is an unknown object that is expected to change. The understanding of relations can radically change when new information is gained about what happened at the crime scene. As shown, students in Group A1 used their representation for presenting this uncertainty with claims such as “everybody is under suspicion” and by graphically expressing relations as hypotheses. The investigation process necessary for understanding the nature of the undefined phenomenon is thus somehow seems to be built into the representation as an integrated part of the representational practice.

Conclusions
In this chapter I investigated the representational practices students in Class A enact while playing Homicide. These representational practices were shown to be parallel in several ways with to the STS-defined scientific inscription practice and MRC. How the students’ practices differ on central points was also shown, including the inquiry process-orientated use of representations. Chapter 5 presented how representations are used for defining the relations between elements of an undefined object rather than representing elements and defending claims about the nature of a stable object. To understand what competences are enacted in the game, we thus have to look at the other aspect of the practice – the inquiry the representation is used for. In the next chapter I focus on how representations are used in the investigation processes.
CHAPTER 6
REPRESENTATIONAL INQUIRY COMPETENCES

The previous chapter initiated the discussion of what competences children engage in the representational practices presented in *Homicide*. The focus was on the practice of representation construction, and how representations were used in student presentations. In this chapter, I take the examination of student competences a step further by looking at the investigative processes the representations are used in. I present data on how students in another class – Class B - used the representations in their investigation of the case, which took place further into the first phase of play after the initial stage of the game. Drawing on Dienna Kuhn’s concept of theory-evidence coordination, I focus on the student inquiry process and how representations take part in this. By the end of this chapter, I propose the term ‘representational inquiry competence’ to describe capabilities that students have for using representations in inquiry activities. This definition contains elements of both inscriptional practice (see McGinn & Roth, 1999), MRC (diSessa & Sherin, 2000) and inquiry competences (Kuhn, 2005; Kuhn, 2002).

Observational setup in Class B

Class B was an eighth grade class in a public school 30 km outside Copenhagen. The majority of the group of teachers running the game in this class had run the game before in another class - Class C, which I report on in Chapter 9. The science teacher and the math teacher were part of the team running the game in both classes. In Class B, a Danish teacher also participated. In Class B, I mainly focused my observations on Group B1, which had a case concerning a boy named Moussa who had been found dead in the local swimming club. The reason for focusing on this group was that it introduced the use of representations in the class and used these (as other groups also did) actively in their investigations throughout the entire game. By focusing on one group’s work, I was able to document and trace the development of their work in detail.

The game ran for a full school week as intended in the game material and was set up in the classroom and an additional classroom. The teachers had set up separate workspaces for each group with tables next to display boards. There were two groups in each classroom and one of the classrooms was separated with display boards so each group had a side of the room to itself. Each group was located next to display boards (see Picture 6.3), but was not encouraged by the teacher to use them before the first status meeting. The reason for arranging with the teachers not to encourage using the boards was that I was interested in knowing whether students would initiate
the construction and use of representations under these conditions and what items in the game-in-school setting world support this development. I present a discussion of this in Chapter 9.

The cordless network in the class was not working properly so each group was given access to one computer in the computer room away from the classroom. They were encouraged to print out game documents and use them at their workspaces in the classroom. The status meetings in Class B were also held around the presenting group’s workstation. All laboratory work was done in the school laboratory away from the classrooms.

6.1: Investigative use of representations in Class B

In this section, I provide an overview of the first phase of Group B1’s development of their representation and then present a snapshot exemplifying how the group used the representation in their group discussions. As described, Group B1 was the first group to start using the display boards behind their table in their workspace. As was the case in Class A, Group B1 used their first representation in the presentation at the first status meeting after 15–20 minutes of playing the main case.

At the first status meeting Tobias presented the victim’s personal data and the data on when, how and in what condition the victim was found. This information is available at the game interface in the autopsy report and the report from the local police. The first stage of the representation, which only contained a minor part of the available information (see Picture 6.1 above), included the Pictures of the victim from the autopsy report (bottom of the board), a description of the victim, Moussa Alaleh (center), the victim’s brother Raat Alaleh (right) and the caretaker, Teddy ‘Hal’
(top), at the swimming club where Moussa was found dead. Tobias presented the characters by pointing at them. At the meeting, the teacher encouraged the other groups to use boards in the same way as Group B1. Other groups said that they had been on the verge of doing the same before the meeting.

After the meeting, most of the groups started to put files on the boards. In Group B1 Tobias left to go to the computer room to take notes from the videotaped interrogations of witnesses and suspects while the remaining members of the group worked on the reorganization of the data on the board (see Picture 6.3).

![Picture 6.3: Katja (black jacket) reorganized the data on the board with the help of the other group members Dorthe (grey shirt), Mark (green shirt) and Jannik (red shirt).]

At this stage, the group organized the data on the board in a system that generally remained the same until the final phase of the game (see Reconstruction 6.1 below). The descriptions of the suspects were aligned over one another on the left side of the board with the data or new information from the technical analysis about that character next to the descriptions. Data on clues found at the crime scene that had not yet been analyzed were placed in the middle of the board. The right side of the board seemed (in the first phase of the game) to host tools for the investigation (such as the timeline) or analyzed data which could not be or had not yet been connected to a specific character. An example of this was the lifted fingerprint the group had glued on a red piece of paper. It had been lifted from the personal belongings in the victim’s locker at the swimming club and a suspect with a matching print had not been identified at this stage in the game.
After the four group members had finished organizing the documents on the board, Tobias returned from the computer room to give the group the information obtained from viewing the videotaped interrogations. In these recordings, the characters are interviewed by a police officer about where they were at what time on the night of the crime as well as their relationship and that of other characters to the victim. The group was assembled in front of the board while Tobias systematically went through his notes concerning the different characters, and either he or Mark pointed at their Picture on the board while the different group members commented on the information.

*Picture 6.4:* Reading from his notes, Tobias pointed at the character Teddy ‘Hal’, who was the caretaker at the swimming club where the victim was found.

When Tobias gave the information concerning time of the different events and at what time the character Teddy Hal was at the swimming club, Katja suggested that they should make one timeline to plot the time of the different events that had occurred and the whereabouts of all the different characters. This started a long dispute between Tobias and Katja in which Tobias argued they should make separate timelines for each character and that the ‘report dude’ should do that. At this point, he pointed at Dorthe and told her that she was the report dude.
Katja again argued that they should make one large timeline containing all the data concerning time. She was supported by Mark, who also wanted to make one large timeline. Tobias argued they had a lot of data on time and Katja replied that this was why having the data collected in one place was a good idea. Tobias then contended that making all the time data fit on one paper would be difficult. This ended in a dispute about who should do what, at which point Tobias told Dorthe to make a list of everything that had to do with time. The disagreement on the design of timelines resulted in a solution intended to favor both sides, as shown in Reconstruction 6.1 of the representation (below). Next to each character is handwritten information about his or her whereabouts at the time of the crime. At the top of the board in the center to the right is also a timeline printed from the game interface with pre-printed data indicating what time the police were alarmed and arrived as well as data on what time Moussa and his friend Peter were excising. The group did not seem to make much use of this timeline during the game though. Their representation kept this overall structure during most of the game.
Character profiles are aligned one over the other on the left side of the board. Data or new information from the technical analyses is placed next to the descriptions. Unanalyzed data on clues found at the crime scene were placed in the middle of the board. The right side of the board hosted tools for the investigation (such as the timeline) or analyzed data that could not or had not yet been connected to a specific character (e.g. the red piece of paper with the fingerprint lifted from the belongings in the victim’s locker at the swimming club) (see also Reconstruction 6.1 below).
Reconstruction 6.1: Reconstruction of the B1 representation in the first phase of the game, early on day two in the game week. Character profiles were aligned one over the other on the left side of the board. Data or results from the technical analysis that point to a character were placed next to the character’s profile (i.e. identified fingerprints) together with information about the time of the characters whereabouts at the night of the crime. Unanalyzed data on clues found at the crime scene were placed in the middle of the board. The right side of the board hosted tools for the investigation (such as the timeline) or analyzed data that could not or had not yet been connected to a specific character (e.g. the papers with fingerprints lifted from the belongings in the victim’s locker at the swimming club).

The objective of this chapter is to understand what competences students engage in the investigation in the game, and what role representations play in this process. Before entering in to the analysis of this I present a snapshot from the group’s investigation process which involves a group discussion concerning what happened at the crime scene in the hours leading up to the death of the victim, Moussa. At this point the group had had access to several different sources of information. One example is that they knew (from the interrogations of the victim’s girlfriend) that the victim had an argument with a boy he regularly swam with named Peter. The night he was killed the victim had made fun of Peter, which had made Peter angry. The group had also had access to interrogations of Peter in which he told the police that he and the victim also had an argument in the dressing room before Peter went home just before ten. The suspect, who proves to be the murderer in the end, had not been introduced at this point. At the start of this situation,
in an attempt to reconstrue the exact time of the crime, the group members named Dorthe, Katja, Tobias and Mark sat around the table in their workspace and discussed what time the victim, Moussa, went into the dressing room.

**Picture 6.7**

Tobias: But he (the victim) didn’t go into the dressing room until about ten, because he talked to his girlfriend Lise first.
Mark: Oh, yes, right. Was it at exactly (points to Tobias (see Picture 6.7)) nine or ten?
Tobias: Yes.
Mark: In that case, I think it’s early 10 (says something inaudible).
Tobias: Yes, that might very well be, because...
(Everybody in the group starts talking all at once.)
Mark: No, listen up. He’s wearing his boxers, so he must have taken a shower.
Tobias: Or was on his way to take one.
Mark: No, because he’s didn’t have his swimming trunks on when he came back
Tobias: Oh, yes, that’s right. That is actually very good thinking (Tobias points at Mark)
Katja: Who says he took a shower?
Tobias: Come on, that’s what you do!
Mark: You do!
Tobias (to Katja): Shhh.
(Some members of the group laugh.)
Mark: You do! You go and wash off the chlorine, any swimmer knows that.
Katja: Yes, well, I don’t shower (gets up and leaves).
Dorthe: Me neither. Yuck.
Ramus: In that case, we can shorten it a little because, what did she say again – hang on.
Mark: That means he definitely died between, errr...
Tobias: Just a second.
Tobias: This means that... (gets up and walks over to the left side of the representation where the profiles and the other data are posted) What was it she said again?
Tobias: (points to the handwritten note next to Lise Bondesen’s data indicating her whereabouts around the time of the crime (Picture 6.8)) She had left for home at about ten.
Mark: She had already left a little before ten.

Picture 6.8
Tobias: (points to the handwritten note next to Lise Bondesen’s data indicating her whereabouts around the time of the crime (Picture 6.8)) She had left for home at about ten.
Mark: She had already left a little before ten.

Picture 6.9
Tobias: Yes, shortly before ten, which means that this is also when Moussa went into the - where do we keep the... (he looks at the board and points to the drawing of the swimming club (Picture 6.9)). Yes, in the dressing room, and that’s where he met Peter, and they had an argument. That would probably have been a little after ten.
Mark: (points to the board in the direction of Peter’s profile (Picture 6.10)) Peter left – he says that he left a little before ten.

Tobias: Yes, I know.

Dorthe: Well, obviously he didn’t.

(Several people speak at once.)

Tobias: He left at ten, so he was home at a quarter past ten.

Mark (interrupting Tobias): Can I show all of you something (gets up)?

Mark: If we could go down and print that one out with the surroundings, we’d see that there is… actually, his house is 500 meters from the road – or from the swimming club - 500 to 700 meters.

Dorthe: That’s not very far.

Mark: That’s not far enough for it to take him 15 minutes to walk home. Unless he took a long detour.

Video observations, Class B, day 2
The situation shows the process the students follow to determine the victim’s whereabouts before his death. The group members were trying to reconstruct what the victim, Moussa, did during the hours leading up to his death. How did the group go about the investigation in the situations described above, and what role did the representation play? In the search for answers to these questions, I leave the data for a moment to introduce a model for analyzing the student’s inquiry practice.

6.2: Inquiry as theory-evidence coordination

Learning how to make inquiries is a central part of what schools would like to teach students, i.e. to teach them how to become independent learners who seek answers to their own questions. When trying to identify inquiry skills, however, we encounter the problem of defining what exactly these skills are, and how to identify them in practice. Kuhn suggests a model for understanding inquiry skills – or what she also defines as “scientific thinking” (Kuhn, 2005; Kuhn, 2002). Kuhn’s model is based on her studies of what inquiry skills imply, children’s abilities to develop these skills, and the conditions which support this development. Learning to learn, Kuhn argues, is the only way to prepare students to be flexible in a future work world where what kind of knowledge will be needed is unpredictable. Kuhn argues that inquiry skills are not intuitively present and cannot be expected to develop as a natural outgrowth of children’s curiosity. Consequently, identifying the skills and the conditions under which they develop is necessary. A cornerstone of inquiry is, according to Kuhn, the thesis, or question, and the evidence that bears on it: “Entertaining a thesis that is understood as capable of being disconfirmed by evidence sets the stage for the coordination of theory and evidence that lies at the heart of inquiry” (Kuhn, 2005, p. 57).

Kuhn’s definition of inquiry skills centers on deciphering the skills engaged in this theory-evidence coordination (Kuhn, 2002). In this case, theory is referred to as a student’s mental representation of reality and evidence is understood as sources of knowing. Kuhn suggests cause and effect as a framework for student inquiry. The focus should be on how multiple forces in complex constellations in the world act on one another as causes and effects. She argues that this framework is accessible to children because, from an early age, they construct causal theories to understand the world around them. These theories undergo revision as children interact and collect evidence. Kuhn argues that this process of theory-evidence coordination does not necessarily take place at “a level of conscious awareness of explicit control” (Kuhn, 2005, p. 61). Gaining control of the process of theory (as “what makes sense to me”) and evidence (as sources of knowing) coordination is, according to Kuhn, central in developing inquiry skills.
To illustrate people’s general abilities for engaging skills of theory-evidence coordination, Kuhn describes how people construct mental models of causal networks in the world. In her book, *Education for Thinking*, Kuhn shows how many people are unlikely to take into account multiple factors that potentially affect an outcome (Kuhn, 2005). Children and many adults often reason by making “inferences of causality about particular factors, while ignoring the potential effects of others” (Kuhn, 2005, p. 65 (italics added)). The factors which are judged causal just need to occur in the presence of the outcome on some occasion. Another often used strategy is “to attribute a phenomenon to a single causal factor, among several present, and dismiss the others” (Kuhn, 2005, p. 65). This phenomenon is known as *discounting*. Kuhn argues that these forms of faulty reasoning provide an avenue for the formation of faulty causal models – which may be resistant to change.

Kuhn describes how inquiry learning requires students to seek new information, interpret this information, and (if warranted) requires them to have the ability to revise their existing beliefs accordingly. She argues, however, that it is entirely reasonably that the new information can be rejected because it is believed to be flawed or irrelevant or because of the strength of other data which have supported a different conclusion. Hence, she contends that what is important is not whether students decide to revise their existing beliefs on the basis of the new information. What is essential, argues Kuhn, is the process leading to the decision of whether beliefs should be revised or not (Kuhn, 2005; Kuhn, 2002). The first part of this process is to evaluate the new information in its own right and to interpret exactly what it does or does not imply. The students then have to connect it to what they already know or understand. To do this, Kuhn argues that students have to be aware of what they think and know. They have to be able to think about their own thinking. Only then, Kuhn argues, can they accomplish the integration of what they already know and what they discover from a new source. This is what Kuhn defines as consciously controlled coordination of theory and evidence and what is expected to happen during inquiry learning. Kuhn proposes three phases which inquiry activities undergo: inquiry, analysis, and inferences (Kuhn, 2005). These phases are briefly summarized below.

In the initial *inquiry phase*, students either do or do not identify a purpose with the activity. Kuhn states how it is crucial that students are able to identify the goal of the activity, and what they should do to achieve the goal. Students must believe that there is something to find out other than what they already know, and that they are engaging in a process to find out. The task objectives at this stage are to access data, recognize its relevance to theory (students’ mental representation of the way the world is) and formulate what questions to ask of the data. Kuhn defines the process of
inquiry learning as the process where thinking with theories (the way young children do) and implicit theory revision transform into an intentional inquiry, or what Kuhn also calls scientific thinking. In this process theory-evidence coordination becomes explicit and intentional (Kuhn, 2005).

In the second phase, the analysis phase, the task objectives are to represent evidence distinct from theory, make comparisons and seek and detect patterns. Kuhn describes how when a discrepancy between theory and evidence appears, students need to construct a relationship between the two:

This coordination requires encoding and representation of the evidence as an entity distinct from the theory, which is itself explicitly represented as an object of cognition. (Kuhn, 2005, p. 84)

As described above, Kuhn emphasizes that the criterion here is not necessarily for the theory to be revised. What is central is that the evidence is represented in its own right, and the implications for the theory are examined. Once the relevance of evidence is established, Kuhn describes how students “must come to see analysis of it” (Kuhn, 2005, p. 78). Kuhn defines this as the identification of patterns and relationships and the coordination of what is observed with existing understandings. Kuhn explains how students also need to develop valid inference strategies for interpreting the multiple causes and effects of the phenomenon under investigation, and in what ways they intersect. One strategy is a controlled comparison in which all features except the one of interest are held constant.

The final phase in inquiry activities is the inference phase, which Kuhn describes as the culmination of the inquiry where the investigators must come to terms with what they claim, and how they know this to be true (Kuhn, 2005). The task objectives here are to draw justified claims, reject unjustified claims, and acknowledge indeterminate claims. In this final phase, data should be presented separately from theories, and drawing on these data should be a basis for inferences. The inquiry, analysis, and inference strategies are described separately in this chapter. Kuhn, though, emphasizes that inquiry processes rarely, if ever, consist of abrupt transition from one strategy to a more advanced one. Multiple strategies coexist and the process is most often a mixture of more or less effective strategies. Development should be seen as a gradual increase in effective strategies over time, awareness of the different strategies, and an enhanced awareness of the goal and the extent to which it is being met by the strategies.
The empirical approach in Kuhn’s work is slightly different from the empery being analyzed in this thesis. Kuhn investigates how students find out what causes affect a phenomenon such as what makes a boat sail faster (the color, size of the sail, or the weight). In the empery of the current thesis, the students deal with a puzzle where they are able to assemble the picture of what happened through results from technical tests and analysis of witnesses’ interrogations. Cause and effect questions such as who and what caused Moussa’s death can still be asked, but the students’ way of answering these questions does not involve the exact same strategies as are available to Kuhn’s students. It is still essential for students to compare evidence to find intersections. Nevertheless, it does not make sense to make controlled comparisons in which all features except the one of interest are held constant in an inquiry where what has already happened is being reconstrued. We thus have to look for different types of strategies. What is essential in both types of situations is the theory-evidence coordination which requires encoding and representation of the evidence as an entity distinct from the theory (Kuhn, 2005).

6.3: Representations in inquiry processes
Let us return to the situations in Class B and look at the different phases of the student investigation processes, and what role representations play at the different stages. In the initial phase of the game or what, with reference to Kuhn, I will call the inquiry phase, Group B1 used the boards for presenting data on the victim, and how and in what condition he was found, as well as data on the related characters. By focusing on the victim, and what had happened to him, the group had, as described by Kuhn, identified the purpose and goal of the activity and engaged in finding out what happened in the case. To achieve this goal they printed out the first data available and constructed an initial representation. The creation of the representation can thus be seen as a first strategy for doing inquiry into the case.

After the first presentation, Tobias went to access the data from the interrogations while the rest of the group collectively started to systematize the data available in the case by reconstructing the representation. When Tobias returned he began reading the notes he took on the interrogations about the different characters’ relationships to the victim, and what they did at what time on the night of the crime. At this point, Katja initiated focusing explicitly on data concerning time. She suggested that the group construct one timeline with all the different data covering what time the characters did what on the night of the crime. She argued that having one place to collect all the data on time would be a good idea. Tobias disagreed, arguing that there were too many data to be able to fit them all on one paper. Instead, he argued that they should make separate timelines for each character.
This discussion can be viewed as a discussion of what strategies to use for comparing evidence concerning time and how the representation should be constructed to support this strategy. Katja suggested a tool for the graphic integration of all the data on time to be able to gain an overview of what characters did at exact times. Tobias suggested a tool to connect data to the character, but also to graphically align them with other characters’ data. The construction of the representation frames the discussion. Both Tobias and Katja expressed their viewpoints in terms of how to structure the representation. These viewpoints are not expressed explicitly as means for supporting the comparison of evidence, and this strategic point is thus implicit in the discussion and might not be consciously controlled reflections on inquiry strategies as defined by Kuhn (Kuhn, 2005). As evident from Reconstruction 6.1, both strategies became present at the representation.

In the first inquiry phase, the group focuses on collecting and systematizing most of the data available in the case at this stage. They print out every character profile as well as unanalyzed clues from the crime scene. They focus on accessing the information from the interrogations first and not, for instance, the technical analysis of clues. They thus engage in accessing different types of data but do not yet engage in building theories about the case. Data on time are the first focal point, and the strategy for comparing what characters did what at what time is recognized. The structure of the representation is used for discussing, for example, what can be defined as representational strategies for searching for answers to the overall thesis in the game, i.e. what happened on the night of the crime and who did it?

The question of time is also central in the situation where the group analyzes at what point in time the victim died. Further into the investigation, the group is now at what Kuhn defines as the analysis phase. At the beginning of the situation, the students sat around a table where they tried to determine the exact time of the crime. As explained earlier, they had access to information from witness interrogations and knew that the victim and the boy he was training with, Peter, had had an argument both around the pool and later on while alone in the dressing room before Peter said he went home. Peter was thus under suspicion when this situation took place, and finding out whether Peter caused the victim’s death is central, which Peter being mentioned midway and at the end of the situation indicate. Nevertheless, note how no theories about Peter’s guilt are expressed before late in the investigation.

The first discussion concerned what time the victim, Moussa, went into the dressing room. From the notes on the interrogation with the victims’ girlfriend Lise, they knew that she said that Moussa
went into the dressing room a little before ten o’clock. Mark then argued that the incident that killed Moussa must have occurred earlier than ten. He concluded this based on the observation that Moussa must have taken a shower as he would otherwise have been found in his swim trunks and not in his boxers. Katja pointed out the uninvestigated link in this claim with the question, “Who says he took a shower?” Katja’s question forced Mark to rethink his implicit conclusion that all people shower after going to the pool. He then defended his line of argument with the idea that swimmers have the experience or expertise to know that they have to wash off the chlorine. In the first part of the situation, the students interpreted the evidence from the interrogation of Peter and Lise and connected them to evidence about what Moussa was wearing when he was found, and theories about swimmers showering to wash off chlorine. Next, they tried to construct a hypothesis on what time Moussa encountered his murderer. They did not at any time in the discussion relate the construction of this hypothesis to theories about who the murderer could have been.

After having established the hypothesis on the sequence of events in the dressing room, the students moved on to determining the exact time that Moussa encountered his murderer. Mark was the first one to estimate the time of death but foundered. Tobias kept his focus on determining what time the victim met his murderer by using a different strategy. He tried to calculate the interval between what time the victim’s girlfriend said he went into the dressing room, and the estimated time the victim must have finished showering. Seated at the table, he tried to remember the details of the evidence he wanted to relate the hypothesis to but could not reach a conclusion. He got up and turned to the representation, where he was able to check the exact information regarding when Lise said she went home and Moussa went into the dressing room. Next to Lise’s information was the map of the dressing room. Tobias then began connecting the data on time with the data on the layout of the dressing room. Using established hypotheses on how long it would take Moussa to shower, Tobias concluded that Moussa would have finished showering a little after ten o’clock. In this part of the investigation, Tobias sought to relate this supposition to existing evidence about time and geographical features of the events. This is a complex action in the case with many types of exact data. At this stage, Tobias used the representation to help him connect the established hypothesis of the sequence of events in the dressing room with evidence on time and then geographical evidence.

Next, Tobias tried to coordinate the hypothesis they had constructed with the theory that Peter was involved in the murder to make inferences of what they could claim based on their investigation. In this instance, he made what Kuhn would define as “inferences of causality about particular factors, while ignoring the potential effects of others” (Kuhn, 2005, p. 65). He stated that Moussa went into
the dressing room, and because evidence shows that he and Peter had an argument, Tobias concluded that this incidence took place at the time the group had estimated the victim ran into his murderer. He ignored the evidence that Peter’s interrogation states he went home at ten. This statement could be untrue, but Tobias failed to construct a relation between theory and evidence by encoding and representing the evidence as an entity distinct from theory, as Kuhn defines it (Kuhn, 2005).

Mark pointed out the discrepancy by physically pointing to the evidence on the representation stating that Peter had said he went home just before ten o’clock. Tobias acknowledged this, but Dorthe tried to maintain the validity of the faulty inference. Mark then tried to construct a relation between theory and evidence by drawing attention to evidence not graphically present on the representation. He claimed that if they could calculate the distance from the swimming club to Peter’s house, they would find that the distance was too short for it to take Peter 15 minutes to walk. They had thus identified another step in the investigation. Implicit in this conclusion was that Peter might not be telling the truth and might have left later than he told the police he did, which means he still might be involved in the murder. The conclusions at this stage were not related to theories or expressed as proof of a theory. Instead, by discussing the distance to the suspect’s house, the students did another test to provide more evidence. The idea was expressed as evidence possibly proving that it could not have taken him 15 minutes to walk the distance. In the next section, I sum up the conclusions of this chapter and discuss what competences students engage in these investigative practices in the game.

6.4: Representational inquiry
What becomes evident after studying the inquiry processes in Class B is how aspects of constructing and using representations change at the different stages of the inquiry. Let us first revisit the different inquiry stages of the various classes with the objective of getting closer to the definition of this mixed representational practice. The analysis of the various situations presented in this chapter show that the focus of the investigation is on constructing evidence-based theories of what time what events took place on the night of the crime, and what characters potentially were involved in the murder. The students’ identification of the goal of the activity and of how to achieve this goal is thus in keeping with the overall objective of the game: That players should do inquiries by developing hypotheses and theories based on analyzed clues and data. This identification of the game objectives is the first stage of what Kuhn defines as inquiry activities (Kuhn, 2005). Accessing data and understanding its relevance to theory in order to transform implicit theory revision to an intentional inquiry is the other central aspect of the inquiry phase.
(Kuhn, 2005). The situation where the group collectively constructed representations shows how they access the many types of data by building a representational structure. An explicit example of this is the discussion between Tobias and Katja about timeline formats. By initiating the discussion of time in response to Tobias reading from his notes from the interrogations, Katja initially drew attention to the idea that they should ask questions concerning the time of the events and compare the characters whereabouts at different times. As argued earlier, the discussion also develops into an implicit discussion of what strategies to use to do this. This is explicitly argued in terms of what structures to add to the representation for it to support the strategies. The representation thus becomes a tool for defining, discussing and visualizing implicit inquiry strategies.

The students engage a dual competence in the process when they transform their activity to an intentional inquiry while constructing representational structures for supporting the inquiry. I see these two elements as interwoven and not as isolated steps that must be taken in a specific sequence. On the one hand, constructing a representational structure makes students discuss strategies for doing inquiry, but the representational structure also makes them aware of and defines their process. We see examples of the latter in Class A in the construction of the group A2 representation where Kristina explained to the teacher that the two blue boxes aligned over one another contained information on what she called the characters’ ‘wishes’ (see Reconstruction 5.2 in Chapter 5). Nevertheless, the boxes show that the one connected to the victim’s name bears the text “was promoted” and the one connected to the victim’s ex-boyfriend’s name bears the text “wish to be promoted”. This shows that only one of the boxes actually contains information on wishes. In Chapter 5, I argue that the graphical alignment of the blue boxes establishes the information about possible motives for killing the victim. The ability to compare the wishes and successes of the two characters reveals that Jens Kaspersen wanted the promotion that Marie Johansen received, and therefore had a possible motive for killing her. The teacher also pointed out to Kristina that the content could be classified as a motive. Again, I will argue that the construction of representation helps students visualize implicit or intuitive inquiry strategies such as comparing evidence. For this incidence, the teacher helped the students define their result, i.e. that they had identified a motive by comparing data. Apparently, however, in both these instances, the students did not move to what Kuhn defines as the meta-level of operation where they are able to select strategies in relation to the goal of the activity. They enter the inquiry by intuitively constructing a structure they believe will help them in the inquiry. As shown in Chapter 5, this representation is also their interpretation of the case. In Chapter 8, I return to the discussion of the different representational formats in the classes.
In what Kuhn would define as the *analysis phase* (Kuhn, 2005), students interpreted and related different types of evidence independent of theories about the suspects in the case. In the process of defining what time the victim encountered his murderer, the representation was used in the process of relating the hypothesis on the sequence of events in the dressing room that the students had constructed while sitting around the table with evidence on the time of events and the layout of the dressing room represented on the board. Tobias also tried to coordinate the group’s hypothesis on what time the victim encountered his murderer with evidence to prove their theory that Peter was the murderer. While pointing at Peter’s profile on the representation, however, Mark pointed out to him that he had ignored data from Peter’s interrogation showing a discrepancy between their theory and the evidence indicating where Peter was at the time of the crime.

I argue that during the process Group B1 uses the representation in their inquiry, it becomes visually evident what hypotheses or theories the students are trying to construct and what is evidence as sources of knowing. The main part of the evidence is on the representation in Group B1, whereas the hypotheses and theories are not. As a result, when the students discuss hypotheses or theories of the case, they are able, as Mark did, to physically point to evidence relating to a hypothesis or, as in the situation just described, to other evidence proving a discrepancy between theory and evidence. In Class A, we also see how group A1 used representations for illustrating hypotheses (see Chapter 5). Martin gave an explanation about the box bearing the information “dealt drugs” connected to both the victim and his friend’s name by saying, “…and they probably have - but we don’t know this yet—but they have probably been dealing drugs together because they were convicted in 2001 of dealing drugs” (See Picture 5.4 in Chapter 5). Martin thus explicitly expressed this feature in the representation as a hypothesis not fully supported by the evidence. Nevertheless, he based his claims on data given in the game (the concurrent convictions) which he related his hypothesis to by pointing at the box with information on convictions on the representation.

This use aligns with McGinn and Roth’s description of the functions of representations in scientific work and how visual representations provide pictorial or graphical inscriptions of the central aspects of the phenomenon under investigation (McGinn & Roth, 1999). As shown in Chapter 5, McGinn and Roth propose that school environments should be organized to allow students to collaborate on constructing visual representations to be used as an integral aspect of argumentation in science education. Aspects of this are also evident in the situations in this chapter. Both Kuhn and McGinn and Roth view the skills as something that students might be predisposed for, but that they need to practice with instruction to master. While Kuhn views
children’s mental models of networks of cause and effect as a potential obstacle to developing inquiry skills, diSessa and Sherin see children’s intuitive ideas as a resource (diSessa & Sherin, 2000). This and the previous chapter show that the same innovative and creative skills go into constructing representations as the ones DiSessa and Sherin describe. Students in both classes have independently invented and used formats for supporting their inquiry. Like the representations described by diSessa and Sherin, the representations in Class A and Class B are abstract. They are not meant to “look like” the represented object like, for instance, technical drawings of objects are, and Chapter 5 shows how the student representations focused on visualizing relations between the elements of the abstract object.

Based on the conclusions in Chapters 5 and 6 I propose the term ‘representational inquiry competence’ to describe capabilities that students have for using representations in inquiry activities. This definition contains elements of both inscriptive practice (see McGinn & Roth, 1999), MRC (diSessa & Sherin, 2000) and inquiry competences (Kuhn, 2005; Kuhn, 2002):

Representational inquiry competence:
The ability to construct, productively use, transform and critique visual representations as an integrated part of doing inquiry into defining an unknown phenomenon.

- Includes the ability to visually represent the phenomena subjected to inquiry and the inquiry strategies that go into investigating the phenomenon.
- Includes the ability to construct and use representations for investigating, coordinating and relating evidence, hypotheses, and theory.

As mentioned earlier, there is an apparent lack of meta-reflection on the representational practice in the described situations. Students do not seem to evaluate or critique the representational formats they use, or construct in the situations presented from Class A and B. In the above definition the ability to critique inquiry representations is included. In Chapter 8, I return the discussion of this and present data illustrating student ability to reflect and critique representational formats. In this chapter I also show how transformation of representations is an integrated part of representational inquiry. In Chapter 9, I return to the analysis of the networks representational inquiry competences are enacted in.

Conclusions
The aim of Part II was to understand what practices are established in the game *Homicide*, and what competences students enact in the various settings of classes playing the game. In Chapter 5 I focused on understanding the representational practices established in Class A. These representational practices were shown to be parallel in several ways to the STS-defined scientific inscription practice, and to differ on central points. One main difference was that representations in Class A were used for defining the relations of elements of an undefined object and investigating and building hypotheses about the nature of this object rather than for defending claims about the nature of a defined object. Chapter 6 focuses on how representations are used in inquiry, and what competences are enacted in these processes. The analysis of Group B1’s inquires in Class B show how representations – which I will also term “inquiry representations” - are used for visualizing inquiry strategies, supporting the encoding of evidence as an entity distinct from theory, and relating established evidence or hypotheses to the body of the complex case. I proposed the term ‘representational inquiry competences’ as a definition of the competences I have observed children engage in the inquiries in *Homicide*. So far, I have only briefly touched on how the representations take part in the inquiry practice. In part III, I gradually change the analytical focus with the aim of coming closer to a definition of the representation as a partaking artifact or actor in the enactment of representational competences, and how these competences are enacted in networks of relations and practices.
PART III

REPRESENTATIONAL INQUIRY IN NETWORKS OF ACTORS

Part III investigates the second part of the research objective: How are competences, learning and tools enacted in networks of related entities in the school settings the game is played in. The perspective in this part changes from focusing on the student enactment of competences to understanding the role of representations and game and school related actors in the enactment of representational inquiry. This change of perspective occurs gradually in Chapters 7, 8 and 9. Chapter 7 introduces the perspective of looking at the role of representations in inquiry and learning processes in systems of artifacts and individuals. The previous chapters show how students develop different formats of representations. In Chapter 8 I seek to understand the mutability of the different formats of inquiry representations as adaptations to practices and relations in networks in the various settings the game is played in. In professional scientific practice, scientists have a repertoire of possible inscriptional formats such as graphs and x-rays photos to choose from, but where do the formats introduced in the classes come from? Chapter 9 investigates this question by drawing on concepts from ANT in an attempt to understand the representations as effects of patterns of school and game related actors.
CHAPTER 7
MEDIATIATION OF REPRESENTATIONAL INQUIRY

So far this thesis has focused on defining the representational inquiry process in Homicide in terms of what competences and practices students engage in the process. In this chapter, I again look at the students’ inquiry but change the perspective in the attempt to understand how the representations students construct take part in the knowledge construction and learning processes in the investigations in the game. Theories of distributed cognition are applied as a theoretical framework for analyzing how learning is enacted in systems of humans and artifacts (Hutchins, 1995). I propose that the inquiry representations can be understood as mediating artifacts that connect students as task solvers and the task of solving the case. By comparing processes of inquiry during the analysis phase in two classes, I show that the different formats of inquiry representations act as mediating artifacts in different phases of the inquiry. In the final section of the chapter, I present how representations transform as a result of progressing inquiry. I argue that students learning about their case and knowledge construction take place as a reorganization of representational structures.

7.1: Inquiry representations in the analysis phase

In this section, I return to Class A and present an example of how the representation in Group A2 was used in the analysis phase (Kuhn, 2005) of the group’s inquiry. By comparing this process to the representational inquiry process we saw in Class B, I attempt to gain an understanding of the role of representations in the groups’ inquiry process and how this role differed from class to class.

In the transcribed situation below Group A2 was preparing for the second status meeting by writing notes to use in their presentations of the case. At the first status meeting, the teacher had asked them to prepare “in the same sort of way as Martin’s group” (See Chapter 5, p. 7). Before the second status meeting, the teacher then told the groups that the representations were not enough preparation for the meeting. They had to write down on a piece of paper what they wanted to tell the rest of the groups about their case. In the following transcribed situation with Group A2, the group member Morten was writing down the information about the characters Kristina provided him with. Kristina was standing at the same table as Morten and pointing to the characters names on the representation while discussing information about them. Another group member, Ole, was sitting next to Morten. In the background, two other girls (Anna and Lena) were working at the group’s laptop. Kristina and Morten had been listing information about the different characters and had started to discuss the data they had on the victim’s sister, Anne Berg.
Picture 7.1
Kristina: But, in a way, I think the woman, Anna Berg, is a little suspicious because she, she… (leans forward and points in the direction of Anne Berg’s name (Picture 7.1))
Morten: We don’t have to solve the murder now, but, yes, you’re right.
Kristina: Yes, because she said (points in the direction of Anne Berg’s name) that … what was it I wanted to say...

Picture 7.2
Kristina: …she said that she had deserved the promotion (points in the direction of the circle with the text “was promoted” (Picture 7.2)) because she was good at her work and devoted to it, right? And that could be because she didn’t want to seem like she wanted to kill her, right?
Morten: Yes, for confusion.
Kristina: It’s also possible that she didn’t know what was going on. Well, we don’t know. That’s why we should maybe also investigate the thing with the footprints to see if it is a man or a woman’s footprints.
Kristina: It’s also possible that she got her son to kill her (points in the direction of the box with the son’s name (Picture 7.3)). Who knows? It could also be Poul Berg (the victim’s boss and brother-in-law).

Anna: (in blue shirt, turns to Kristina and starts talking to her while counting on her fingers (Picture 7.4)) Anne and Jens (the victim’s ex-boyfriend) and the boss.
Kristina: It could also be her son (points in the direction of the box with the son’s name (Picture 7.5)
Anna: Whose son?
Kristina: Anne Berg’s son (points at the son’s name again).
Morten: Peter Berg is also a suspect in another case.
Anna: We also have him as a suspect in the case about the fight on the Tuesday.
Kristina: What? Peter?
Anna: No, not Peter. We’re talking about the boss. I don’t know what his name is.
Kristina: Poul. His name is Poul.
Anna: Because they had a fight on the Tuesday
Kristina: Who?
Lena (t-shirt): Marie and the boss
Kristina: Ahh, I’ll write that down, too (turns to write on the representation but turns back to direct the next question to the girls behind her). When was she found?
Anna: Wednesday.
Lena: But, it was the Tuesday before.
Kristina: The week before.
Anna: No (turns to Lena (Picture 7.6)).
Lena: It wasn't the Tuesday where she was reported missing...
Kristina: I think this is confusing.
Morten: It’s a good piece of information. We’ll have to correct it.
Kristina: We’ll just leave that out. It just doesn’t fit if her temperature was 16 degrees and it was the day before she had the fight with her boss.
Morten: No.
Ole: Yes, because it could have taken some time before they reported her missing.
Kristina: Maybe it’s a week before. But, if it had taken a week, she would probably be filled with insects.

(Video observations, Class A, day 2)

Looking at this situation in terms of representational inquiry shows some of the same uses of the representation as in Group B1, where the members in the group discussed characters while pointing to them (see Chapter 6). The analysis phase of the inquiry in Group A2, and the reaction to the discrepancy between evidence and theory however differed in key ways in contrast to the analysis phase in Group B1. The situation with Group A2 starts with a discussion between Morten and Kristina about the possible motives of the victim’s sister, Anne Berg. Kristina argued that Anne was suspicious because she was too positive in the videotaped interrogation about the sister deserving the promotion she got before she died. Kristina sees this as an attempt to cover up that she is the killer. Anne Berg is married to the victim’s boss, Poul Berg, who had an affair with the victim just before she died. In the discussion with Morten, Kristina pointed out that they still did not know how much Anne Berg knew about the affair. As a result, she might not have a motive for killing her sister. Kristina also pointed out that the group therefore had to analyze the footprints found at the crime scene to find out if they were from a man or a woman. After this, Kristina started guessing about possible suspects before she was interrupted by Anna, who listed the three possible suspects. Anna and Lena had focused their work so far on listening to and taking notes from the videotaped interrogations. After some confusion about the names, Anna and Lena explained that new evidence existed against the boss, Poul Berg. He and the victim apparently had a fight right before the victim was reported missing. This led to more confusion. Kristina claimed that their calculations of the time of death did not fit with the time of the fight. The body could not have cooled down to the temperature it had when found if the victim had died the day before. The discussion ended in confusion about whether the fight was the day before or the week before she died. Either way, the group’s calculations of time of death did not fit with this new piece of information. Regarding the discrepancy between the new information and the data containing the groups’ calculations, Morten wanted to correct the notes on sequence of events, while Kristina did not want to write the new information on the representation as it did not fit with the calculations.
What is the role of the representation in the analysis phase (Kuhn, 2005; Kuhn, 2002) in this group’s inquiry compared to the inquiry situation with Group B1 presented in Chapter 6? Both groups were trying to build hypotheses about who committed the murder, but the representations were central at different stages in these discussions. Initially, Group B1 sat around the table and discussed the specifics of the victim’s whereabouts before he died and then got up to discuss the established hypothesis in connection to information available on the representation on the board. In Group A2, the discussions initially centered on the representation with Kristina pointing to boxes with characters’ names while their behavior and possible motives were discussed. At the end of the situation, the representation is no longer central in the discussion of the discrepancy between the time of the fight between the victim and her boss and the groups’ calculations of the time of death. Why is this so? In an attempt to answer these questions I propose a theoretical approach for understanding the different roles of representations in the students analysis phase.

7.2: Distributed cognition in systems of individuals and artifacts

In his book, *Cognition in the wild*, Edwin Hutchins presents the fundamental idea that cognition is situated and socially distributed in a socio-cultural world (1995). As described in Chapter 1, the book is based on a study of how navigation is performed by a team on a modern navy ship that Hutchins uses as the unit of cognitive analysis. The basic idea in Hutchin’s theory is that human cognition always is situated in a socio-cultural world and never unaffected by it: “It is about locating cognitive activity in context, where context is not a fixed set of surrounding conditions but a wider dynamical process of which the cognition of an individual is only a part” (1995, p. xiii).

Hutchins applies the metaphor of cognitive science and cognition as computation (information processing) to the operation of the system of ship navigation as performed by a navigation team. By analyzing the processes involved in navigation, Hutchins argues that cognition is a system of humans and artifacts that combined enact learning. First, Hutchins describes how the team members use different technologies to solve the navigational task of getting the ship from one point to the other. These techniques and technologies all attempt to respond to the same question: Where am I?, although in different ways. Next, Hutchins defines the navigational task by analyzing what lies between the relationship of the ship to its environment and the position plotted on the chart. He states that between these two elements, “lie a number of representational media across which the representations of the spatial relationship of the ship to the world are propagated” (Hutchins, 1995, p. 119). An example of this is the transformation of a spatial relationship between the ship and a fixed landmark into what is called the alidade gyro compass system. In this system, two compass scales are superimposed on what the telescope shows. As a result, the spatial
relationship to a lighthouse located on the landscape in the vicinity of the ship becomes propagated to a particular point on the compass scales. The point is then written down in the bearing log and the visual reading is then assigned a particular written number in the log book. Accomplished in a cycle of activity, the representations of the position of the ship take a variety of forms in the different media on their way from the telescope to the chart, as follows:

The basic procedures of navigation are accomplished by a cycle of activity, called the fix cycle, in which representations of the spatial relationship of the ship to known landmarks are created, transformed, and combined in such a way that the solution to the problem of position fixing is transparent. (Hutchins, 1995, p. 117)

Hutchins points out that the meaning of transparent is defined by properties of the processor that interprets the output from the cycle. Hutchins argues that the fixed cycle implements a computation (information processing) and thus, cognition. This definition avoids defining cognition as something that takes place in an individual’s mind and in a community of people. Hutchins believes that cognition is enacted in a system made up of humans and artifacts. This involves the creation, transformation, and combination of representations of the spatial relationship to the ship. Hutchins writes that “representational states are propagated from one medium to another by bringing the states of the media into coordination with one another” (1995, p. 117). When describing how the states of the media that representations propagate through are brought into coordination in systems of humans and artifacts, Hutchins establishes the concept of mediating artifacts. Hutchins defines a mediating artifact as an artifact that mediates the relationship between the performer and the task:

Rather than focus on the mediating artifact as something that “stands between,” I will view it as one of many structural elements that are brought into coordination in the performance of the task. Any of the structures that are brought into coordination in the performance of the task can be seen as a mediating structure. It is difficult in this context to say what stands between what, but they certainly all participate in the organization of behavior. (Hutchins, 1995, p. 290)

A written procedure is used as an example of a mediating artifact. The written procedure, for example, organizes the performance of a task where the order of organization is essential. The procedure tells the actor to perform the task following a specific sequence of steps. The written procedure thus becomes the mediating structure between the performer and the task. The theory of distributed cognition implies, however, that the performer and the task should not be viewed as
independent entities but as part of a system. Rather than seeing the mediating artifact as something that stands between the performer and the task, Hutchins contends that it should be viewed as "one of many structural elements that are brought into coordination in the performance of the task" (1995, p. 290). These mediating structures can be embodied in artifacts, ideas, and systems of social interaction or in all three at once (Hutchins, 1995).

7.3: Inquiry representations as mediating artifacts
Hutchins developed the theory of distributed cognition, providing it with a lens for understanding cognitive activity in systems of artifacts and individuals. But how should we apply this approach to analysis of the role of representations in knowledge construction in students inquiry processes? Where do we direct the attention? Latour formulates in a review of Cognition in the wild what he views as the key to Hutchins theoretical approach:

The first point is not to follow mental or individual activities but trajectories of modified representations. In other words, there is not, according to Hutchins, any meaning in the expression "I think" or "I represent." What can be documented is a shift in representation through different media. For instance, it is not observable in the chart itself, but it is there in a group trying to make features of the landscape correspond with features on the chart. There is no meaning in asking what is in the mind of the plotter. But there is meaning in observing how the plotter coordinates various media – bearings reported on the phone by the Pelorus operators, instructions precoded on the chart, orders from the captain – in one single line on the paper.
(Latour, 1996b, p. 56)

When seeking to understand the cognitive processes or information processing processes in the representational inquiry, it is thus the trajectories of modified representations we have to look for and the shift in representation through different media. We have to look not just at artifacts such as the students’ representations, but at how elements of, for instance, the criminal case are made to correspond with the representations. We have to direct our attention to how various medias of representational states of elements of the game such as videotaped interrogations, written notes on paper, and verbalized data from character profiles are coordinated. In the following I attempt to apply the approach of distributed cognition to situations from Classes A and B presented in this and the previous chapters to define the role of the representations in the cognitive activity in the two classes. I also attempt to compare the knowledge construction processes to understand the differences between the activities in the two classes.
When looking at the representational inquiry processes in the different classes, the groups in Classes A and B appear to be trying to answer the same question: “Who did it?” To answer this question, the groups went through processes of collection and translation of evidence, such as taking notes from videotaped interrogations, analyzing physical clues in the laboratory, and looking at maps of the fictive town to understand the whereabouts of the characters the day the murder was committed. The representational inquiry processes that groups in Classes A and B engaged in did, though, as presented in previous chapters, differ in certain ways and had different focuses. As shown in Chapter 5, Group A2 translated data from the character profiles into a graphical network of connected names and the characters’ interests. This suited the focus of their interest or understanding of what the task was, i.e. mapping relations among characters and their data.

In attempting to understand the process of Group A2 in terms of theories of distributed cognition, let us first look at the media that representations of the game characters propagated through, and how this trajectory modified how characters were represented. In the situation where Group A2 constructed their representation after the first status meeting (see section 5.2), they printed the papers with the character profiles first. The characters’ data and information about relationships thus transformed from a digital form to a printed one. Morten then read the written details about their connections to other characters’ convictions, etc. to Kristina, and they discussed the person in relation to the position of the name on the representation. The textual representation of the character becomes a verbalized object of discussion that has been modified to be a representation of the characters’ relationship to the victim and other characters and what sentences this character may have. When the students had decided how to map the character relations and possible convictions, as well as what to relate the information to, Kristina wrote the name or information in a box or circle on the poster. The representation of the character as a verbalized object of discussion is propagated to particular graphics written on the paper. The complex representation of the character is modified to a defined graphic representation of the character’s relationship to the victim and previous sentences. Through this process of the propagation of the representations of characters over different media, the representation of game elements are made to correspond with the student representation of the criminal case scenario.

We see similar processes in Group B1. The B1 representation contained, apart from the character profiles, additional types of information from the game scenario that the A2 representation did not have, including printed descriptions of clues, notes the students wrote while listening to the videotaped interrogations, and results from the analysis of physical clues (such as lifted fingerprints) (see Reconstruction 6.1 in Chapter 6). Representations of elements of the game thus
were distributed across one or several media to become part of the representation on the board. When listening to the videotaped interrogations, students wrote notes that were discussed in Group B1 next to the board (see Picture 6.5). The focus of the students’ note taking was, as shown in Chapter 6, the time of the characters’ whereabouts on the night of the crime. Representations of characters’ whereabouts and relationships propagated initially from the video media to the written media and then to a verbalized media in the group discussion about timelines that took place around the board. The verbalized representations of time then propagated to the text media as students made various timelines. In the propagation process across several media, video representations of characters had been modified to be representations of the time of the characters’ whereabouts on the night of the crime. The relationship of the character was not made to correspond with a relational structure as in Group A2, but with a timeline structure of the individual time data listed one over the other on the representation (see Representation 6.1 in Chapter 6). After the time-representation had become part of the students’ representation, the modification of the overall representational structure continued. I return to the discussion of these representational transformations later in this chapter.

Both classes have the propagation of representations of game elements over media. The representations of game elements such as fictive characters are modified to correspond with the specific structure of the representation the group made. As explained earlier, Hutchins describes how representational states “are propagated from one medium to another by bringing the states of the media into coordination with one another” (1995, p. 117). Hutchins establishes the concept of mediating artifacts to describe how the states of the media that representations propagate through are brought into coordination in systems of individuals and artifacts. In the following, I attempt to understand how the states of the various media are brought into coordination with one another in Classes A and B for the students to be able to construct hypotheses and build theories in the representational inquiry processes in the two classes.

During the situations observed in Classes A and B, it seems that students take notes, print papers or discuss data on character profiles to be able to include the information in their representations. In Group B1 Tobias returned to the board to discuss the notes he wrote after listening to the interrogations. This situation developed into a group discussion on how to design and include timelines on the board with the representation. In Group A2 Kristina and Morten discussed the character profiles and focused on how to include information about the characters relation to other characters in the representational structure on the poster. The end goal of the student work was of course, as described earlier, to solve the case by providing answers to the questions “who did it?”
and “what happened?” But the representations in Classes A and B seems to have the function of coordinating the processes of connecting data by being an artifact that is able to contain representations of elements of the undefined case at a certain media state. The coordination takes place in the process where representational states of elements such as characters propagate over various media with the aim of being included in the student representations.

I thus argue that the inquiry representations act as a mediator in the construction of hypotheses and theories by coordinating the connection of representational states of evidences in the case which propagates to the textual media of the inquiry representation. The iquiry representations can thus be argued to share similarities with the mediating artifact as defined by Hutchins (1995). But the representations also differ in central ways from the types of mediating artifacts such as written procedures or charts, which are predefined formal objects used in navigation that are connected to a set of defined procedures. The inquiry representations do not require users to follow a certain predefined sequence of steps as is the case with written procedures. The artifact and representational inquiry performance is also defined in the course of the game and shares (as shown in Chapter 5) similarities with inquiry performance in relation to scientific inscriptions and models. I return to the discussion of the nature of inquiry representations later in this chapter.

7.4: Mediating formats

The different formats of representations in Classes A and B also play a role in the mediation between the performer and the task at the different phases in the inquiry process. Returning to the situation with Group A2 presented earlier in this chapter, it became clear that the use of the representation changed during the process. At the beginning of the situation, Kristina used the representation in her argumentation about the suspects’ possible motives. She pointed to the boxes and lines and used the details about the relationships between the characters in hers and Morten’s construction of a hypothesis. She also discovered weak links in the hypothesis she was trying to construct and demonstrated that they had to measure footprints to find out if the murderer was a woman or a man. She started to list the possible suspects but was interrupted by another member of the group, Anna, who contributed with the new piece of information that the boss is also under suspicion as he had a fight with the victim before she died. This changes the situation. Kristina started to discuss this new piece of information, which is confusing when compared to the group’s earlier calculations of the time of death. The representation is not used in this discussion, and there is a good reason for this. The A2 representation does not contain time data on the different characters or the technical data used in the calculation of the time of death, such as the temperature of the body when it was found. As shown in Chapter 5, Group A2
constructed and defined their representation in terms of how the characters in the case were related to each other and what wishes, successes, sentences, motives, and memberships they had. The A2 inquiry representation was therefore not able to act as a mediating artifact in the analysis phase of the inquiry process to coordinate the propagation of representational states of clues and time data. In the situation presented in this chapter the representation changes from being a central mediating artifact in the students’ development of hypotheses based on relations between the characters, to failing to mediate in the coordination of a theory on the relationships between characters and new evidence based on technical data. The inquiry process ends in confusion.

The process in the analysis phase in Group B1 differs from the above process. In the representational inquiry situation in Group B1 (in Chapter 6), the students sat around a table first and discussed the details of when the victim went into the locker room and when he had finished showering. When the hypothesis concerning the time of these events was established, the group used the representation to coordinate it with other evidence in the attempt to build theories about whether a certain character was involved in the crime. As described earlier, this led to a long discussion about the whereabouts of a character named Peter around the time when the victim was killed. In this process, the hypothesis that the group had just constructed was related to evidence on what the different characters had said about where they were at the time, maps of the town and verbalized judgments based on data from maps showing how long it took to walk from the swim club to the suspect Peter’s house. In response to the discrepancy between their hypothesis on what time the murder was committed, what time Peter said he left and their theory that Peter killed the victim, they decided to analyze the map and the surroundings near the swimming club again to calculate the distance and compare their answers to how long the suspect said it took him to walk home. In this situation, the students used the representation for connecting evidences and responding to the discrepancy between theory and evidence by encoding evidence distinct from the theory that might create a new relation between the two (Kuhn, 2005). The B1 inquiry representation is able to mediate this process in the analysis phase of the groups’ inquiry. They constructed an artifact which mediates coordination of representational states of time, characters, clues, and results from technical analyses in the theory-evidence coordination process in the analysis phase of the inquiry.

The different formats of representations might act as mediating artifacts at the different phases of the inquiry defined by Kuhn (2005). Chapter 5 showed how group A1 in the initial inquiry phase used their representation for building preliminary hypotheses about character relations, and thus established a focus for further inquiry. Subsequently, their representation acted as a mediating
artifact in the first inquiry phase. Group B1 did not establish hypotheses about events or relations in the initial inquiry phase. In this group the representation was, as shown, able to mediate theory-evidence coordination in the analysis phase of inquiry. As a result, the inquiry representations in the two groups can be argued to act as mediating artifacts in different phases of the inquiry. So far, representations have been treated as stable artifacts. In Chapter 5, I emphasized how representations represent the shape-changing object of a case in the process of being defined. In the final section of this chapter, I present how representations in Class B also physically changed shape over the course of the game.

7.4: Learning as transformations of representational structures
In this section I begin the analysis of transformations of representations that will be further elaborated upon in Chapter 8. In both Classes A and B, I observed how the inquiry representations that students constructed were transformed or redesigned as a part of the students’ inquires. In the last part of this chapter I explore transformations of the Group B1 inquiry representations in terms of cognitive changes and learning. In Group B1 I observed how transformations of the representation appeared to be an integrated process of the investigative work. The group members moved files on the board or applied new files during their group discussions while working on a specific technical analysis, and whenever the work in the laboratories or interviews with suspects furnished them with new results. The physical nature of the board made it possible for the group members to move files around and change the structure of the representation as they worked. After a basic structure had been established in the beginning of the investigation (as described in Chapter 6), the representation thus gradually changed as the group’s inquiry process progressed. These changes were made as the group obtained results from technical analyses such as fingerprints or DNA analysis, or from analyses of video taped interrogations with suspects. As described in Chapter 2, more data also gradually became available to students as they progressed with their analyses and inquiries.
In an informal interview I conducted while the students in Group B1 were working with their case, the group members explained how they worked with information on the board by moving it around. They described how information about clues that the group did not yet have results on was placed centrally on the board. When the clues had been analyzed, such as the broken lock from the victim’s locker with fingerprints on, the identified fingerprint was placed next to the character it belonged to. The initial information about the locker was then moved to the right side of the board to be grouped with the completed analyses. A comparison of Reconstruction 6.1 (Chapter 6) of the representation in the first phase of the game to Picture 7.7 of the B1 representation in the late phase of the game indicates that the group, overall, maintained the work process they described, throughout the game. On Reconstruction 6.1 the data on the characters are located on the left side of the board and information about clues found at the crime scene are placed centrally on the board. On the right side of the board, there are several working papers and a poster with a fingerprint. In the late phase inquiry representation in Picture 7.7, the character data have more information connected to them, such as lifted fingerprints and voice analysis. Two more characters were also added to the left side of the board. Some of the information from the center of the board was moved or exchanged with other information. The right side of the board is empty so the group must have decided not to hang the initial information about analyzed clues on the board. The overall transformative process has thus been to move the representational states of analyzed clues from the area for unanalyzed clues in the middle of the board to the character the clues were identified as being connected to.
These transformations as part of the students progressing inquiry can be explored from the perspective of cognitive change (Hutchins, 1995). As described in Chapter 1, Hutchins argues that the proper unit of analysis for talking about cognitive change includes the individual as well as the socio-material thinking environment. In keeping with this, learning should be understood as an adaptive reorganization in a complex system, i.e. the process by which an individual learns to perform a task can be seen as “a wave of organization moving across a complex set of media” (Hutchins, 1995, p. 310). This propagation happens both to and from external and internal media. Hutchins talks about changes that happen inside an individual as adaptations to organizations or structures in other parts of the larger dynamic system the individual is part of. If, however, this system of artifacts and humans is dynamic, examining both the internal and external adaptations is relevant.

In this case, how do we view the transformations that occurred in Group B1’s representation in light of this theory of learning? I argue that the structures of the mediating artifacts in Class B adapt to the group members’ new state of knowledge. When the students construct new knowledge about a represented element on the board or relations in the case as a whole, the group members move the files, fingerprints, or notes to another place to connect them with a another element represented on the board, i.e. the character whose guilt they point to. On the other hand, one could also argue that the structures in the B1 representation as mediating artifacts also change the process of knowledge construction. In the situation in Chapter 6 where Group B1 is trying to determine the time of death of the victim, the adjacent map of the swimming club made it possible for Tobias to connect statements from the victim’s girlfriend and to map actions that may have occurred in the locker room. Earlier in this chapter, I also argued that the structure of the A2 representation blocked theory-evidence coordination and the construction of hypotheses by not mediating representational states of the technical aspects of the investigation. These examples illustrate how the adaptation and change of structures in the representational inquiry are integrated. To construct new knowledge, the mediating artifact must allow the actor to bring representational elements from the game world into coordination with each other. To carry out inquiries, however, the human actors must be capable of bringing these structures into coordination. I thus argue that student learning concerning the case is an effect of the integrated interplay between inquiry representations and individuals. The transformations, which are an expression of the learning taking place, are the result of structural changes in the individual and the mediating factor. The students learning in their case is thus an integrated process of reorganization of representational structures. In Chapter 8 I continue the analysis of the transformative nature of representations.
Conclusions

In this chapter I applied Hutchins’ theory of distributed cognition to analyze how inquiry representations take part in the students’ knowledge construction and in their learning about their case. I argue that the inquiry representations can be understood as mediating artifacts that connect the students and the task of solving the case. Inquiry representations mediate this process by bringing the states of media of representational states of game elements into coordination with each other. The coordination takes place in a process where representational states of elements such as characters propagate over various media with the aim of being included in the student representations. By comparing the representational inquiry process in the analysis phase in Classes A and B I, showed that the different formats of inquiry representations in the two groups act as mediating artifacts in different phases of the inquiry. In this chapter I showed how transformations of representations were an integrated part of inquiry in Group B1. I argued that student learning concerning their case and knowledge construction takes place as an reorganization of representational structures.

The inquiry representations, however, also differed in central ways from the mediating artifacts of navigation described by Hutchins (1995). In the navigation processes described by Hutchins, the team uses formalized artifacts such as written procedures and charts that are not constructed anew every time the ship leaves harbor. When playing Homicide, students invent and construct their own procedures and formats of mediating artifacts while re-representing the data. As previous chapters have shown, this artifact, and thereby the mediating structure, is defined in the beginning of the game in both Classes A and B. In Chapters 8 and 9, I focus on understanding the networks of actors in which the different inquiry representational formats are enacted in.
CHAPTER 8  
MUTABILITY OF REPRESENTATIONAL FORMATS

The previous chapters have demonstrated how different classes constructed a variety of representational formats for diverse purposes. Chapter 7 introduced the term ‘mediating artifact’ as a definition of the role of representations in the inquiry processes in Class A and B. I also showed how the B1 representation was transformed as part the group’s investigation and argued that learning is enacted through structural transformations of representations. In this chapter, I look at how the variety of formats found across the different classes transforms as part of the representational inquiry they take part in. I apply the theoretical approach of ANT to understand the mutability of inquiry representations and how they adapt to practices and relations in the network they are part of. To understand the student inquiry practices and strategies, I use data from an interview completed in Class B in which the students evaluate the representations from Class A. In addition, I present how students enact meta-representational inquiry competences in evaluating other types of representations. In Chapter 9 I extend the perspective on actors in networks to understand and summarize how human and non-human actors influence the enactment of representational inquiry competences in three different classes.

8.1: Transformations of representations

The previous chapter introduced how representations in Class B gradually transformed as part of the student representational inquiry process and knowledge construction over the course of the game. In this first section I present how inquiry representations in both Class A and B also were redesigned in the late phase of the game. This data are discussed in section 8.2 where I seek to understand the mutable nature of inquiry representations and the related representational inquiry practices by applying theoretical perspectives of ANT.
An example of redesign of representations was seen in Group A3 in Class A in the late phase of the game. The group had produced Inquiry Representation A3A early in the investigation process (Picture 8.1 above) that was similar to the representations constructed by Group A1 and A2 at the same phase in the game. Representation A3A contained all the initial information about the murder victim (Adam Krogh) and his relationship to suspects and witnesses in the case. The victim was represented by a yellow square box in the middle of the representation, relationships was represented by lines and suspects by colored boxes. In Representation A3B, which was created in the late phase of the game, the complexity of Representation A3A was reduced to a simpler design focused on the three prime suspects: Said, Preben, and Ole (see Picture 8.2 below).
Picture 8.2: Representation A3B, created in a later phase of the game, mainly contains information about the weight of two central suspects: Preben and Ole. The group used information about the weight of the characters to calculate whether footprints at the crime scene belonged to either of the two suspects Preben and Ole. The names of three prime suspects, Preben, Ole and Said, are connected to the name of the deceased, Adam.

At this stage in the game the group was investigating whether a footprint that had been found near the dead body of the victim, Adam, could be associated with any of the prime suspects. The weight of the person the footprint belonged to could be calculated from the depth of the footprint found. The students had included data on the weight of two suspects, Ole and Preben, that were available in the character profiles in the game material. The question “Footprints?” was also connected to each of these characters as well as the word “violent”, in reference to Preben’s personality. In a short open interview conducted while the group was working on the representations, a girl from Group A3 described the difference between Representation A3A and A3B as follows:

Girl: (Pointing to A3B) This is just an investigation of whose footprints they are and the other examinations we’ve made. And this one (pointing to Representation A3A) is a poster so we more easily can work out who it is. So we can get an overview of who we think it is. This one (pointing to Representation A3B) is more of an investigation of some of the things we’ve done. And this (pointing to Representation A3A) is a quick overview of all the people in the case.

(Video observations, Class A, day 4)
Representation A3B is described as “an investigation”, whereas Representation A3A is described as “an overview”. Both drawings use boxes that are connected with lines. This and the girl’s focus on the representation as an “overview of the people in the case” show that Representation A3A was produced in the first half of the game as a representation of all the characters and relations at a time when the group had to make sense of the piles of data in their case. At the time when Representation A3B was produced, the group was in the late analysis phase of their inquiry and had been working on the investigation for several days generating results from the technical analysis of clues as well as from taking notes from the interviews with the suspects. Focused on representing characters and their relation to the deceased (similar to the representations constructed by Group A1 and A2 in the same class), the A3A representation did not contain representational states of clues or other technical data. Consequently, Representation A3A could not act as a mediating artifact this late in the analysis phase of the students’ inquiry process.

Representation A3B is structured around representing three suspects and the specific data associated with these characters. Data on the weight of two of the characters are included and connected to them with lines as well as the question “Footprints?” The task was, as described, to find out whether the footprints found in connection with the murder belonged to any of the suspects. Upon calculating the weight of the unknown person who planted the footprint near the body, the group would be able to go to the representation and compare their result to the data on the prime suspect to find out if the evidence points to the guilt of one of these characters. The students had thus created a representation could act as a mediator in the analysis of this part of solving the case. This example illustrates how the students dealt with the fact that the first inquiry representation they created, Representation A3A, was not able to mediate investigations in the analysis phase. Being an “investigation diagram” representation, A3B was created for some of the same practices in the analysis phase of the inquiry process as the representation in Group B1 in Class B. The resulting creation of Representation A3B, however, included both representational states of character relations, illustrated with lines connecting characters, and representations of technical data such as weight.

Group B1 in Class B also reshaped their representation on the fourth day of the five-day game. The main part of their papers and Pictures were moved from the board they had used throughout the game (Board 1) to a board next to it (Board 2). Board 1 contains a Picture of the prime suspect, his data, and the results of the analysis of clues that point to his guilt (see Picture 8.3 below).
The profiles and data on the rest of the characters in the case and the results from the group’s analysis of clues were moved to Board 2. The structure of the representation before the reshaping persists on Board 2, with the characters and their data grouped on the left side of the board. The structure on Board 1 has changed; the main suspect is in the middle of the board and the descriptions of clues that prove his guilt are to the right.
In a semi-structured interview with two groups in Class B conducted after the game that focuses on understanding the criteria for the construction and use of representations, Group B1 explained that they reconstructed the representations because the boards were “getting too cramped” with data that was not related directly to the prime suspect. They explained how too much disorganization would make it too difficult and time consuming to find the files needed for the reconstruction. When asked if they were using the new structure for presenting the reconstruction of the crime or for planning it, they answered that it was for both. They also explained that part of the reshaping of the representation was to get rid of files that had proven not to be important clues due to the results of the investigation.

As discussed in Chapter 7, these transformations can viewed as students learning taking place as an adaptive reorganization in the thinking environments of the students and the representations (Hutchins, 1995). The transformative processes could also be viewed as an adaptation to a new situation or a new practice at the end of the game. The structure of Representation B1 has, as described earlier, acted as a mediating artifact in the complex analysis phase of the students’ inquiry by coordinating representational states of diverse elements of the case. The final inquiry phase of the game is what Kuhn calls the “Inference phase” (Kuhn, 2005). This is described by Kuhn as the culmination of the inquiry where the investigators must come to terms with what they claim and how they know this to be true (Kuhn, 2005). At this point, the objectives of the task are to draw justified claims, reject unjustified claims, and acknowledge indeterminate claims. Board 1 contains, as described, representations of what the group believed to be the prime suspect and the clues that had been analyzed that pointed to his guilt. This board could thus be seen as the group’s visualization of what they claim and how they know this to be true. At the same time the representation on Board 1 can be used as a mediating artifact in the inference phase of the inquiry process where students have to come to terms with what they claim and with what evidence they generated that supports these claims. The conclusion which is visualized is still complex as none of the suspects in the two case have confessed to committing the crime. The representation thus has to visually express their best guess. The data presented in this first section of the chapter thus suggests that representations are redesigned when they are not able to mediate representational inquiry in the specific phase of inquiry. In the remaining part of Chapter 8 I attempt to understand the mutable nature of inquiry representations as in relation to the practices it is an effect of by applying theoretical concepts of ANT to the analysis (de Laet & Mol, 2000).
8.2: Mutability of inquiry representations

Previous chapters presented how students constructed different formats of representations as part of the inquiry process. The formats differed not only within the same class or group but also across classes. A common feature of the different types of formats is that they were all used in the investigative work done in the different classes. How they mediate a variety of processes in the different phases of inquiry has also been shown. The aim of the final section of Chapter 8 and Chapter 9 is to investigate what practices and relations influence, and are influenced by, the construction and transformation of different formats of representations. Because the focus is on understanding artifacts and competences enacted by individuals, I draw on ANT concepts and its broad definition of “actor” in an attempt to gain an understanding of representations and representational inquiry competences as enacted in networks of related practices and human and non-human actors.

As described in Chapter 1, actors are defined in ANT exclusively by their relations to other actors in a network (Latour, 1999b). These related entities “take their form and acquire their attributes as a result of their relations with other entities” (Law, 1999, p. 3). This radical relational network understanding implies that actors not are defined in terms of inherent qualities, but solely in terms of relations to other actors. ANT makes no distinctions between human and nonhuman or micro and macro, but sees these divisions as outcomes or effects of the network (Law, 1999). As described in Chapter 1, classic ANT has been criticized for its focus on power strategies and stabilizing processes in networks. In “after ANT” it has been argued that ANT analysis must pay attention to both mutability and what makes objects stable and immutable to gain a full understanding of these objects (Law & Singleton, 2005).

"After ANT" offers a perspective for looking at the transformations of the inquiry representations and the practices and competences related to these transformations. In their article, *The Zimbabwe Bush Pump: Mechanics of a fluid technology*, de Laet & Mol develop the metaphor ‘fluid’, which becomes a central metaphor in after ANT. As described in Chapter 1, De Laet and Mol define the concept of “fluidity” an investigation of what makes an African bush pump an appropriate technology (de Laet & Mol, 2000). The authors define this widely-used Zimbabwean bush pump as an appropriate technology in terms of its fluid nature; it is adaptable, flexible and responsive to different contexts. It is solid and mechanical but mutable in several ways as it travels around to the communities in Zimbabwe, where community members replace broken spare parts with what is at hand. But de Laet and Mol argue that the fluid nature of the bush pump extends the mechanics of the technology:
The Zimbabwe Bush Pump is solid and mechanical and yet, or so we will argue, its *boundaries* are vague and moving, rather than being clear or fixed. Likewise, the question as to whether or not the Bush Pump actually *works*, as technologies are supposed to, can only rarely be answered with a clear-cut ‘yes’ or ‘no’. Instead, there are many grades and shades of ‘working’; there are adaptations and variants. Thus the fluidity of the pump’s working order is not a matter of interpretation. It is built into the technology itself.

(de Laet & Mol, 2000, pp. 225)

The authors investigate the vague and moving *boundaries* of the object as well as the *workings* of the technology in terms of its successes and failures. In an investigation of the boundaries of the Zimbabwean bush pump, they reach the conclusion that the boundaries are hard to define. The bush pump is a water-producing device that can be defined by the mechanics that make it work as a pump. But the pump cannot provide water and health unless there is a drill to dig the well, the related manuals for drilling and the necessary measurements and tests are done. The pump also needs the village community to drill the well and maintain the pump. The bush pump thus has a number of possible boundaries. In some ways it can be defined as a small device and in other ways it encompasses the entire village community. The authors conclude that the bush pump is framed in a variety of ways. They also state, however, that this variety does not include anything. The pump can be set apart from competing brands of water pumps and the collective event of drilling a well in the village cannot be compared to that of burying a neighbor together. The authors thus argue that the bush pump’s various boundaries define a limited set of configurations and that they each enact a different identity of the pump:

In each of its identities the Bush Pump contains a *variant* of its environment. This also more sharply frames the question about whether or not the Bush Pump succeeds in its activities, since this is different for each of its identities.

(de Laet & Mol, 2000, p. 252)

The success and failure of this fluid actor thus have many grades depending on the enacted identity of the Bush Pump. The pump may provide water but not health, or it may provide health in the dry season but not in the rainy season. De Late and Mol argue that the pump’s mutability is thus not solely due to mechanical changes, but also to the gradual, changing practices and fluid relations that define its success. It is a fluid actor and not an actor in the sense of being a stable set of relations in the way actors are defined in classic ANT.
How well does the concept of fluid actors work for understanding the representations the students construct and work with? In this Part III of this thesis I seek to understand how inquiry representations and representational inquiry competences come to be and develop in the game/school context. In this investigation the network understanding of after ANT and the broadly defined concept of the fluid actor open the perspective for us to pay attention not just to the agency of individuals but also to the mutability and agency of non-human actors. Applying the ANT definition of actors to the analysis of representational formats implies that we understand inquiry representations as entities that take their form and acquire their characteristics as a result of their relations with other entities (Law, 1999). This chapter focuses on understanding transformations of inquiry representations in relation to student practices, while Chapter 9 broadens the perspective to include other actors.

This and the previous chapters have presented how different formats of inquiry representations transform and adapt to the different practices in the various phases of the inquiry process. There do, however, seem to be different modes of transformations and adaptations of representational formats and practices in the various phases of the inquiry process in the different classes. The groups in Class A initially constructed immutable representations that focused on character relations. Additional representations that also included technical data from the investigation were later drawn in the analysis phase. Group B1 in Class B had a different strategy. This group constructed a representation with inbuilt mutability, which made it possible for it to adapt to act as a mediating artifact in the different phases of inquiry. The media the representations were created on was an influential factor in whether the representations were able to mutate. The representations drawn in Class A could only be extended as wide as the size of the paper permitted. Made with pen and paper, reconstruction was only possible on a new piece of paper. In Class B, representations were made out of papers on boards, which in itself was a mutable format. But the boundaries of the inquiry representation extended beyond the paper and boards. The previous chapters show that the inquiry representations in the two classes acted as a representation of both the students’ translation of the case and of their inquiry strategies. At the same time representations also acted as a mediating artifact that mediated the process of hypothesis construction.

In their attempt to understand the workings of the fluid actor, de Laet and Mol pose the question “Is it an actor – does it work?” concerning the Zimbabwean bush pump. If the same question is posed regarding the inquiry representation, it becomes evident, as was the case with the bush pump, that there are grades of working. The initial representations constructed in Class A were
successful in speaking on behalf the students’ translation of the case in representing the network of relations. These representations also worked as mediating artifacts in the initial construction of hypotheses about relations of characters, but failed in coordinating theory-evidence processes in the analysis phase by not representing technical elements of the case. The representations in Class B, on the contrary, failed to work as a mediating artifact in hypothesis construction in the initial inquiry phase, but successfully mediated theory-evidence coordination in the analysis and inference phase of the inquiry.

The students in Class B also described their different representational inquiry strategies in relation to their representations in a semi-structured interview completed with Group B1 and another group in the class after the week of playing the game (see Chapter 4). The interview focused on their work with the representations and criteria for this work. As part of this interview, I presented Pictures of the A1 representations made in Class A and asked the Class B students to compare them to their own representations. Initially, the comments made generally indicated that the Class A representations were confusing. When asked why they thought they were confusing, Tobias from Group B1 answered that it was difficult to get an overview of where the different information on the different characters was when it was not represented by a Picture:

Tobias: If, for instance, you want to find the one that is all the way up there (points to a box on the Picture of one of the Class A representations), then you might start at the bottom of the drawing and go through everything to finally discover that "oh it was at the top".

Lars: But also because you have fingerprints next to the profiles and then you can walk over, and look and compare. And you have everything you’ve found on them, there (points to the board with the B1 group’s representation) with the DNA and frequencies.

(Post-interview with students, Class B)

The lack of detail that Lars pointed out was expressed by all the students as the main difference between the two types of representations. The students agreed that this was one major inconvenience regarding the other class’ representation.

Lars: Then they don’t write everything that is written next to this guy Said over there. They don’t write that in those boxes (points to the B1 representation).

Mette: The small things can be pretty important.
Researcher: Here, for instance, they have "caught drunken driving", right (points to the Class A representations)?

Tobias: Yes, yes.

Lars: Yes.

Tobias: But the voice analysis, that one, they can’t place in there. It’s pretty essential in this case because there is someone who has made an anonymous call to the police where you find out that it’s Martin Bryder, right?

Researcher: Hmm (nods in acknowledgment).

Tobias: But, I would find it a little difficult to draw something like that next to Mark Bryder (points to the printed data with the voice analysis on the B1 representation).

Researcher: Yes.

Tobias: There’s also all these numbers that I don’t get at all (points at the print of the voice analysis on the B1 representation again).

Mette: Also that, you get Pictures of the person and little details that you can look at.

Tobias: Which can actually become pretty important.

(Post-interview with students, Class B)

When asked what the representations of Class A have that their own representations do not have, the students in Class B recognized that it was easier to get an overview of the relations in the case using the Class A representations compared to their own. When asked about what the important criteria for the representations were, the students again pointed to the importance of the inclusion of details about characters and clues, and to the importance of having space for extending the representation with new information.

In the interview, the students spoke about the lack of detailed information in the Class A representations as a major inconvenience. This could, however, also be an expression of the difference between the various practices related to the different representations. Lars talked about how the representations in Class B had all the details about each character on the board, making it
possible for them to “walk over, look and compare”. This was convenient when fingerprints or DNA profiles needed to be identified. At the same time Lars expressed that clues linked to the characters were also kept on the representation. This practice of comparing data seems to be what defines the success of the Class B representation according to the Class B students. Another criterion defined in the interview was the ability to continuously change and extend the representation. As shown in the previous chapters the students in Class B reshape the representation by analyzing clues on the board. The discussions in the group also include analysis of data such as the distance from the fitness center to the suspect’s house. Seen from this perspective, the Class A representations are very inconvenient as they lack the data necessary to analyze the clues. The practice that defines this representation’s success is being able to gain an overview of the network of relations as was the case in the example with Group A3.

The two types of representations constructed in Class A and B are thus defined by different relations and practices. But they are also defined by some of the same relations and practices. They are used as central inquiry tools in both classes for constructing hypotheses in the theory-evidence coordination in the inquiry process, and as representations of the groups’ translation of the case. Thus there are objects that we can define as inquiry representations in both classes but which are defined by different relations and practices in the different phases of inquiry. Using the terminology of de Laet and Mol, these different formats can be understood as different identities (de Laet & Mol, 2000) of the inquiry representation. These different identities can be defined in terms of their successes and failures in the different practices in the different phases of the inquiry. The initial Class A representations, which were successful in mediating the processes of hypothesis construction in the initial inquiry phase, can thus be defined in terms of being an immutable mobile used for relational inquiry; the Class B representation, which was successful as a mediator in inquiry in the late analysis phase, can be defined in terms of its mutable adaptable nature in this phase. Drawing on the de Laet and Mol terminology of identities we still need to understand how related entities in the various settings in classes playing the game Homicide influences the various identities of inquiry representations. I analyze this further in Chapter 9.

**Conclusions**

This chapter investigates the mutability of representations in the late phases of inquiry in Class A and B. As discussed in Chapter 7, these transformations can viewed as students learning taking place as an adaptive reorganization in the thinking environments of the students and the representations. The transformative processes could, however, also be viewed as an adaptation to a new situation or a new practice at the end of the game. The conclusion reached is that the
inquiry representations act as a shape-changing actor with different identities enacted in networks of fluent student relations and practices. De Laet and Mol’s concept of fluidity is used as an approach for analyzing mutations of representations. There are, however, several crucial points where the object of the representation differs radically from De Laet and Mol’s Zimbabwean bush pump. In the data presented from the two classes (and in a third class that will be presented in Chapter 9), inquiry representations are invented in the initial phase of the inquiry process. The inquiry representations are thus not a piece of pre-constructed technology that adapts to the environment it is placed in as a Zimbabwean bush pump placed in a village community does. In the next and final chapter of this thesis, I attempt to understand what aspects of the game-school environment enact these inventions and their various identities.
CHAPTER 9
NETWORKS OF REPRESENTATIONAL INQUIRY

The previous chapter presented how the inquiry representations shared characteristics across the changing settings in which they were enacted even though they were enacted in different identities as an effect of changing student practices and relations. In this chapter I attempt to identify the related actors that influence the construction and transformations of the different versions of inquiry representations and representational inquiry. This chapter should, however, not be seen as an exhaustive analysis of inquiry representations as a result of networks but as a mapping of patterns of related actors in order to provide an overview of the complexity of the relational network. The mapping is inspired by theories of “multiple enactments of objects” (Mol, 2002). This chapter furthers the line of thinking taken up in Chapter 8 by viewing the versions as patterns related actors in the particular classes in which the game Homicide is played. The empirical outset of this chapter is data from the third class I observed, Class C, which will be discussed in relation to the two previous studies in Class A and B.

Observational setup in Class C
Class C was from the same school as Class B and was made up of ninth graders aged 15–16. The game ran for five school days, three hours a day including breaks. The teachers in charge decided to only spend half the amount of time recommended due to time constraints, and because they believed that this bright, highly articulate ninth grade class would be able to finish the game in half the time. The game had not been used in the school before (Class B played the game subsequent to Class C), so the teachers' knowledge about the game stemmed from the instructions in the teacher's manual and the two to three hours of introduction provided by the researcher. The game was run mainly by an experienced science teacher assisted periodically by a math teacher and a Danish teacher.

The school had good science facilities, and the teachers wanted to set up the game in the laboratories with laptops and a wireless network. Unfortunately, technical problems with the laptops and running the game online prevented this. The teacher in charge therefore decided to move the class to the school's computer room. The game is designed for each group to have access to one computer and then to print out central documents to work on them around tables or in the school laboratories. Setting up the game in the computer room meant that the groups had access to more than one computer per group. A second consequence of setting up the game in the
computer room was that students worked in rows in front of computer screens instead of around group tables in the classroom.

![Picture 9.1: Students working in rows in the computer room.](image)

The only separate table with a computer was the teacher’s desk, which one of the groups used during the game. The teacher’s desk also had a white board behind it (see Picture 9.2). Apart from the white board behind the teacher’s desk, there were also display boards on the other walls in the computer room.

![Picture 9.2: Group C1 at the teacher’s desk in front of the whiteboard.](image)

There were no tables without computers that the students could use for discussions away from the computer screens. The introduction to the cases and status meetings with the teachers were done in the classroom away from the computer room, whereas the main part of the work done between status meetings was done in the computer room. This resulted in a situation where the main part of the interaction in the game was in front of or with computers. As described in Chapter 3, despite the change in the game’s setup, I decided to proceed with the observations in Class C as I hoped it
would create a contrast case to the previous studies that would provide insights into the conditions under which representations were constructed and developed.

Early in my observations, I began focusing on Group C1, which had the case with the victim named Niels Andersen. This group sat at the teacher’s table (see Picture 9.2 above) facing the rows of tables where the rest of the groups sat. They were the only group in the class that had a whiteboard next to their table. The reason for this observational focus was that this group was the only one in the class that started using the white board in their case early in the main case. In the following, I describe the initial process of this work to understand how it was initiated and developed. In this class, in collaboration with the teacher, I experimented with not providing the students with paper, boards or other materials for making representations. In addition, the teacher’s introduction at the beginning of the game did not encourage students to hang things on boards or draw representations. The reason for making this design experiment was that I wanted to see whether the students would start producing their own tools without being encouraged to do so and without being provided with suitable materials.

9.1: Representational practices in Group C1

The C1 Group independently started drawing on the white board before the first status meeting. Two boys (Mikael and Jakob) took the initiative to find pens and begin drawing. Before the group started drawing, one of the teachers, Signe, asked one of the other four group members to write down the information on the board on a piece of paper. While Jakob was drawing and writing on the board, a girl from the group (Tanja) wrote down the information from the board on a piece of paper without copying the drawing. Initially, Jakob started drawing on top of the pictures from the character gallery from the game interface projected onto the white board (see Picture 9.3 below).
While he was drawing, he received instructions from Mikael, who was retrieving information from the character profiles, about what information to include on the white board. The group had written the names of the victim, Niels Andersen, and the two central characters, Ulla Winter and Flemming Berggren, on the top of the board. Jakob then drew the shape of a face with a question mark in it using one of the suspects’ faces from the projection of the character gallery as a template (See Reconstruction 9.1). Underneath the face he had drawn, he wrote "suspect". Mikael told Jakob to write the weight of the unknown murderer they had calculated from the footprint impression found at the crime scene. While Jakob was writing the data given to him, Mikael and another group member discussed the size of the footprint found at the crime scene, how to calculate the shoe size from the footprint measurements, and which suspects it might fit. Jakob started drawing a new head and wrote the name of one of the suspects, Ulla Winter, next to it and then added information about the character from the case file. Meanwhile, one of the girls in the group had calculated the shoe size from the length of the footprint found at the crime scene by measuring the feet of one of her classmates and comparing them. The footprint found at the crime scene belonged to a rather large foot, leading two group members to discuss whether the calculation was correct and whether Ulla Winter could be excluded as a suspect because her feet were small. Jakob kept writing information about the suspects on the board. At this point, the science teacher, Ole, came into the computer room and Jakob told him that he was writing facts about the characters and the unknown suspect on the whiteboard. Shortly after this, the situation presented below took place. Ole and I, the researcher, stood beside the board and were talking about whether to make poster-size paper
available to the class for the students to hang items on the walls. Ole turned to the white board to comment on Jakob’s drawing:

Ole: Jakob, it would probably be a good idea if you wrote your chart on some cardboard so we can take it with us when we leave.
Jakob: But this looks more professional.
Ole: We don’t have the room the whole day.
Jakob: We have some paper where we can write it down.
Tanja: Ole, we have written it down.
Ole: Good.
Jakob: That means it’s filed.
Ole: Good.

(Video observations, Class C, day 1)

Ole and I continued our conversation and agreed to make poster-size paper available at the next status meeting. Although the rest of the class was later offered materials, none of them used them in their investigation process during the game. Most groups produced presentations at the very end of the game. Group C1 did not use the board at the status meeting held in the classroom away from the computer room.

Reconstruction 9.1: The representation made by Group C1 in Class C showing how it looked before the first status meeting.

The objective in this chapter is to understand what related actors or entities influences the enactment of representational inquiry practices and competences. After having seen different
formats of the representations presented in three different classes we could also pose this question in more pragmatic terms: Why is the same kind of representation created in different formats across classes and schools? What influences this construction? Briefly leaving the practices of Class C, I return to the discussion from Chapter 8 on inquiry representation as an actor of different identities.

9.2: Multiple enactments of objects

To discuss this, I turn to Mol’s analysis of medical practices, which shares similarities with the object of study in this thesis (Mol, 2002). In her book, *The body multiple*, Mol investigates the ways in which Western medicine deals with the body and its diseases. She explores “the ways in which medicine attunes to, interacts with, and shapes its objects in its various and varied practices” (Mol, 2002, p. vii). The problem explored in Mol’s book is that in health care different practices may produce a variety of diagnoses for individual patients. Mol bases her arguments on studies of practices related to the disease atherosclerosis. What might be diagnosed as an obstruction in a blood vessel after a radiographic investigation may not be discovered and investigated in a subsequent ultrasound measurement of blood flow. Consequently, the professional has to sort out what to believe about the different diagnoses of the same disease in one patient. This can be viewed as different perspectives on an underlying disease due to the use of different diagnostic techniques, but Mol poses the argument that the account of realities and the realities that they describe are produced together. Her central point is that a disease such as atherosclerosis should not be seen as something one has but as something which is enacted. The disease does not exist independent of the practices which manipulate, articulate and define the relevant actions to be taken in relation to it.

Mol uses the example of surgery and rehabilitation as two clinical versions of the disease. In the surgeon’s version, the disease is tackled through tests and surgical procedures on the patient’s body. The other is rehabilitation, which depends on collaboration between the patient and the physiotherapist. These two versions take place in different places and involve different actors which lead the patient to see and enact different versions of the disease. Mol thus argues that the disease is “multiple”: it is enacted in multiple versions in different practices. These versions are also partly connected. Mol states tension can exist between the multiplicity and connectedness: The surgeon’s advice to the patient is to practice walking, but it is the physiotherapist who has the resources to get the patient to exercise (Mol, 2002).
This analysis contributes a central after ANT point: Different networks exist that produce a variety of versions of a phenomenon dependent on what practices they are enacted in. The central focus in ANT is on understanding these different versions and their overlapping relations, effects and practices (Gad & Jensen, 2007).

How does this model work for understanding the object of inquiry representations enacted in the game *Homicide*? In the previous chapters, I have argued that the various representations and related practices in the different classes can be defined collectively as inquiry representations, but are also variants of the student practices and competences enacted in the particular classes playing the game. The previous chapters have thus presented some of these identities, such as how representations both act as materializations of students’ translation of the case and as mediating artifacts at different phases of the inquiry process. In Chapter 8 I thus argued that the inquiry representation could be understood as a fluent actor of different identities and that each of these identities contained a variant of the environment in which they were enacted. Mol’s model of multiple enactments, provide an additional perspective for understanding the networks of related actors in which representational inquiry competences and inquiry representations are enacted. In the following I thus seek to identify related actors of the different networks in the various settings the game is played in and discuss how they produce and shape the various versions of inquiry representations and representational inquiry.

**9.3: Representational inquiry enacted in networks of actors**

The situation with Jakob and Ole and Group C1 helps provide an understanding of what related actors influenced the initial representation construction process. Why did this group start drawing a representation on the board as part of their work? In answering this question, let us first look at Jakob’s response when the teacher suggested writing it on paper instead. He argued that it looked more professional on the white board. What could professional possibly mean to him in this context? The obvious answer would be that it refers to the simulated forensic profession in the game and that Jakob believes the practice of using representations for the investigation work on the board is closer to how this profession actually operates. Another possible answer could be that it relates to the school practice and the cross-disciplinary science teaching situation in the school. In the semi-structured post-interview with Class B (see description of setup in Chapter 4), I asked Group B1 and another group what initially made them construct representations on the boards:

**Researcher:** Both groups, I think it was your group (points at the B1 group) that started hanging things on the boards. Can you remember why you did that?
Mark: We actually did it because you see them put things up on TV, right? But it’s logical that you need to organize it instead of just keeping it in a folder.

(Tobias smiles in response to Mark’s comment)

Researcher: So it was because it looked like something in the criminal cases?

Mark: Yes.

Researcher: It’s a crime mystery, so why not?

Mark: I don’t think that the police have seen it. I just think that they think that there is more order in it and that it is better for comparing.

Researcher: Okay.

Tobias: Well, initially I thought “cool I’ve seen this on Mobile Task Force (Rejseholdet)”. I put it up – up with it, and then after a couple of minutes, I thought this is actually pretty cool because it is much clearer than having it in a folder and having to flip through all the different ones. Then you can just quickly, for instance, with the DNA analysis, take it down and see if it fits instead of having to remember and things.

(Video taped post-interview with Class B after the game week)

A reference is once again made to the police profession familiar from detective series such as CSI or the Danish series Mobile Task Force. The representation is defined as something created to mimic the picture they have of professional forensic investigation methods. The B1 group members then expressed how they first created the representation and then discovered its primary use as a tool for systematizing and comparing data.
The professional police practices familiar from television can be seen as an influential entity in the initial situation where the students decide to make the representations. In the initial inquiry process the students are motivated to start the construction of the representation because of the image they have of how investigators use boards to put pictures and data on when investigating a case. The fictitious police profession can therefore be defined as an actor students relate to in creation and shaping of the inquiry representations. After the students had constructed the representation they described how they discovered what processes in the inquiry it can be used for. As has been presented in the previous chapters, representations adapt to the different inquiry processes of students in the different phases of inquiry. Boards and poster-size paper may be influential actors in this process.

Creating representations by hanging items on display boards or drawing on poster-size paper hung on cupboards above the tables has in the previous chapters been defined as an integrated practice in the inquiry process in Class A and B. In Class C the C1 group was the only group that had access to a whiteboard. In the first part of the game where the group started to draw their representation, none of the other groups were offered (or requested) posters to draw on. Hence Group C1 was the

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4 Picture retrieved from http://dr.dk/ April, 2008
only group in Class C that used a representation in their inquiry. In the above it was argued that professional police inquiry methods were an influential actor in the student enactment of representation construction. This initiation may only take place, however, if a suitable media is available. It could thus be argued that media such as display boards, poster-size paper and whiteboards are entities that influence the initiation of construction of representations. In Chapter 8 I argued that these media also are influential factors in shaping the representational formats and functions in the particular classes. Class A did not have access to boards but was given poster-size paper. Made with pen and paper, the representations constructed in this class were immutable as reconstructing them was only possible on a new piece of paper. The poster media however made it mobile and allowed students to carry it to meetings or other groups’ workspaces. The groups in Class B had display boards around their workspace which made the construction of the mutable paper-on-boards format possible. Group C1 in Class C had a whiteboard where pictures from the character gallery from the game interface could be projected on to, to be used to create the mutable but not mobile unknown-suspect-focused representation.

The whiteboard in Class C thus also make a relation to another actor possible. As described earlier, the online material from the game contains both a gallery of characters and provides the students with a graphical example of how a gallery can be constructed (see Pictures 2.2 and 2.3 in Chapter 2). In the representation construction process in Group A2 (Chapter 5) students had this graphical example on the table amongst their working files but did not use it in their translation process in the situation presented. The student representations in Class A and B also differ in design and purpose from the pre-produced character gallery, which suggests that they are not used directly as templates. In Class C, however, the whiteboard made a more direct inspiration from the game material possible. When Jakob first started to draw the representation, he did it on the projected image of the gallery of characters (see Picture 9.3). In spite of the resemblance to the original, Jakob created a different focus in the representation by drawing a face with a question mark labeled ‘suspect’ in the middle of the whiteboard.

The boards, walls, interfaces and posters are thus influential actors in the construction of representations in the different classes. Why then do the other groups in Class C not use the display boards on the walls in the computer room for making representations? The particular set up of the classroom might be influential in this. Compared to the other classes, students in Class C had access to one computer each instead of one computer per group. While the computer in the other classes is seen more as an extended database (as intended by the game design), it is possibly seen as “where the game takes place” in Class C. Most of the interaction took place with
the students seated each in front of their own computer. As a result, students also started printing files from the game interface later in the game than Class A and B. Most of the groups worked with their files on the computer instead of with printed files. The online work may have lessened the students’ need to make a physical tool for representing the physical representations of files and elements in their case. Group C1 was the only group in Class C that chose to use just one computer. Their work with creating representations without the use of the computer could thus have been viewed as “not part of the game” by the other groups in the class. In this context, the computer is an actor that when present in large numbers destabilizes the creation of inquiry representations.

The teacher, however, is also an influential actor in the network in which the inquiry representations are enacted. The teachers in Class A and B, in contrast to the teacher in Class C, praised the initial attempts to use representations in front of the rest of the groups at the first status meeting. In the situation presented in this chapter with the teacher, Ole, and the student, Jakob, the teacher did not directly discourage the group’s work, but suggested they draw the representation on paper instead. The reason for this is that other classes use the computer room and the representation might have gotten erased when other classes used the room during the week the game was played. Jakob continued the work arguing that it looked more professional to draw on the board. Another girl in the group assured the teacher she had written the information down on paper. Thus, the teacher and the computer room facilities in Class C are influential actors in de-establishing the representational inquiry practice, but their influence does not obstruct the creation of representations. The students’ solution to the situation was to make a representation that satisfies their need for working professionally and to take notes that satisfy the teacher’s need for them not to lose data. In Class C the teacher also did not encourage the use of representations in the presentations at the status meetings as was the case in Class A and B. In both Class A and B the recruitment of teachers as allies meant that the groups in the class made representations resembling the format of the first group presenting inquiry representations. Teachers are thus actors in the general acceptance of the representational inquiry method and enactment of representational inquiry competences in the classes.

As described in Chapter 4, I did a semi-structured interview with the teachers from Class B and Class C after the game. Part of the objective with this interview was to understand if the representational inquiry processes observed in the classes were an element of their normal teaching practice and the weekly class work outside the game. When the teachers were asked whether they normally worked with boards in other subjects in the same way it was done in
they replied that they did not work much with hanging things on boards as they did not have many educational materials which supported this kind of work. They also replied that it would obviously be a good idea to work with boards in other project-based work. When asked what was good about this method, they replied that the work on boards gave them as teachers a clear picture of where the students were in their investigations. By looking at the boards they were able to follow what guided the investigations from day to day. According to these statements students did not often use boards as tools in their work in other subjects. Whether this meant that they had not worked with representational inquiry before was not determined in the interview as the definition of this practice had not been completed at this stage in the data collection process. The statements from the teachers as well as the answers from the students on their motivation for initiating constructions of representations, however, show that the representational inquiry practices in Class B and Class C were not directly influenced by the everyday educational practice but that the teachers encouraged the work.

Another potential actor was the complex game structure of the main case. As shown, students did not engage in the construction of representations before they got to the main case in the game. Neither of the classes observed made representations while playing the game’s intro case on the first day. The intro case, which is simpler, involves three suspects and a victim. As described earlier, the case is designed to allow students to become familiar with the interface as well as the different forensic techniques. Hence, the situation is vastly simpler with only one type of data and vastly fewer characters compared to the main case. Instead of constructing inquiry representations, students took notes and wrote short reports for the class presentations. This practice is in contrast to the work carried out for the main case where – as shown – representations are produced within the first twenty minutes of play before the first status meeting. This could suggest that the complexity of the case is an actor that influences the enactment of representations. The intro case is not complex enough for the students to need a tool for the aforementioned purposes, such as systematizing and comparing different types of data.

In this chapter I have identified possible actors that influence the construction and transformations of the different versions of inquiry representations and representational inquiry in the different contexts in which *Homicide* is played. It is beyond the scope of this thesis to provide an exhaustive account of how networks of entities influence the enactment of different versions of inquiry representations, but the mapping of networks in this chapter provides possible anatomies of such networks. One possible pattern of relations is that the students create representations inspired by the police practice, but not before complexity becomes present in the main case. The presence of
character galleries on the interface with reference to the police practice might have been the source of inspiration, but the boards and walls present around the workspaces influence the shape, function, and transformation of the representations. Although the boards influence the structure and function, the practice of representations did not spread to the other groups when the game was seen as taking place in the computer, or when the teacher did not encourage the use of tangible representational tools. These networks of actors and practices can be viewed as patterns of relations which enact a particular version of the inquiry representation and practice of representational inquiry. Though consisting of the same actors the pattern of relations changes from class to class and, as shown in Chapter 8, within the setting of the class. In the discussion chapter of this thesis I review the overlapping relations, effects and practices of the versions.

**Conclusions**

The objective of this chapter was to understand the network of related entities in which inquiry representations and the related representational inquiry practices and competences are enacted. The analysis in this chapter shows that the construction and shape of the representations depend on patterns of related actors in the particular networks in the settings the game *Homicide* is played in. Related actors include fictional police professions, teachers, and computers. It was argued that these patterns of relations enact inquiry representations in a variety of shapes and designs with different functional foci. The patterns of relations both changes from class to class and within the setting of the class. As has become clear in this thesis, however, it is not just inquiry representations that are enacted in particular networks of actors. It is also the competences that go into conducting inquiries by creating representational structures. Thus the students’ representational inquiry competences are also enacted in different versions in the networks of entities in the particular setting in which the game *Homicide* is played.
CHAPTER 10
DISCUSSION AND CONCLUSIONS

In this thesis I have investigated practices observed in classes playing the game Homicide. Questions concerning what inquiry practices, tools, and competences are enacted in the networks of game-base learning environments in schools have guided this study. In the first half of this chapter, I revisit the conclusions made in the different chapters and discuss the competences defined in this thesis in relation to formal science curriculum goals in Denmark and professional practice. In the second half of the chapter I discuss the overlapping relations, effects and practices of the different versions of inquiry representations defined in Part III of this thesis in relation to further understanding of representational inquiry competences, learning processes, and game development. In the last section of this chapter I point to the implications of the network approach taken in this study and how it can be further developed in future DBR, learning game studies.

10.1: Representational inquiry competences in schools and professions

The first half of the analysis, Part II focused on understanding what competences and practices were enacted in the classes playing Homicide. Chapter 5 presented how students used representations as materializations of their translation of the case. From a STS perspective the groups established a two-way connection between the complex disorganized case, with its many fictive characters and files of technical data, and a two-dimensional structure focused on relational matters in the case. An immutable mobile of the case was thus created that could be carried to meetings or to other groups’ workspaces to be used for presenting and discussing hypotheses without changing shape. By translating files given in the case into a representational structure of the groups’ versions of the case, a relation was built between the representation and students which gave the mutable mobile the power to speak on behalf of the case. This position was further strengthened by the recruitment of the teachers as allies who supported the relational format. This led to the further construction in other groups of relational-focused representational versions. The representational practices, however, also proved to differ on central points from STS-defined inscriptive practices. Chapter 5 presented how representations are used for defining the relations of the elements of an undefined object under investigation rather than for representing elements and defending claims concerning the nature of a stable object, which is how the use of mutable mobiles is described in STS (Latour, 1990). With the objective of defining the competences students enacted in their representational work, an understanding of the other side of the practice was necessary: the inquiry the representation is used for. To shed further light on this, Chapter 6 focused on understanding the aforementioned inquiry processes and how students used
representations in their investigations. I showed how representations help students relate evidence and coordinate it with constructed hypotheses and theory. This led to the proposed definition of ‘representational inquiry competences’ as the ability to construct, productively use, transform and critique visual representations as an integrated part of doing inquiry into defining an unknown phenomenon.

These competences are defined based on the analysis of the game Homicide played in schools. But how does the representational inquiry competences relate to the official curriculum objectives? In Denmark the official curriculum goals are described in the Ministry of Education’s overall guidelines titled Common goals (Fælles mål) (Ministry of Education, 2008). Currently under revision, the guidelines are the binding national goals in Denmark. The descriptions of the final objectives for chemistry, physics and biology education are of interest in this discussion because they are described as guidelines and the point of orientation for science education in the upper secondary classes the game is designed for (Hansen, 2006). The aforementioned descriptions are divided into sections labeled either according to the knowledge content (such as ‘environment and health’) or to the methods (‘the world of physics and chemistry’) students are expected to know and be skilled in using when they graduate. Inquiry methods are referred to in the curriculum where the final objectives are described for biology, physics, and chemistry. The most direct reference is in the section entitled ‘working methods and mindset’ which appears for all three subjects. For biology, it states:

The teaching should lead to students acquiring knowledge and skills which make them capable of:

- Identifying and formulating relevant thesis and outlining hypotheses.
- Planning, completing, and assessing inquiries and experiments in the field and in the laboratory.
- Using information technology in connection with seeking information, data collection, analysis, and presentation...’. (Ministry of Education, 2008)

These and similar descriptions in the final objectives for physics and chemistry correspond with the overall inquiry stages students go through in their investigations in the game Homicide. They formulated theses and hypotheses and planned, completed and assessed the inquiries and experiments done during the game. There are, however, central differences between the final objectives described in the official curriculum and practices and competences we have seen enacted in Homicide. The descriptions in the guidelines are subject specific whereas with Homicide, students handle inquiries with many types of data from different disciplines. The inquiry in Homicide is cross-disciplinary and operates on two levels. On one level, students have to plan and carry out, for instance, laboratory tests. On another level, they have to connect and coordinate the
results from these tests with their theories. The students use inquiry representations when they coordinate the information. The revised version of the curriculum goals focuses extensively on inquiry methods, whereas the use of representations or inscriptions is not mentioned in the objectives for individual subjects. An important finding in this thesis is that when *Homicide* is played in schools, the inquiry practices and competences we have seen are closely integrated with the competences used for innovating representational formats. Representational inquiry competences thus involve central skills described in the Danish science curriculum objectives. But the competences defined in this thesis are also an extension of science curriculum inquiry descriptions because they involve capabilities for constructing and using representations for doing inquiry.

Part II of this thesis presented how elements of the epistemology of representational inquiry are parallel to epistemologies of scientific inscriptive practice. This includes practices of the construction and transformation of representations and inscriptions. McGinn and Roth describe how scientists create initial representations in the field or laboratories, and how these formats undergo a series of transformations as the scientist tries to make sense of the phenomenon (1999). They describe how these transformations “are part of the ‘sanitization’ process in scientific publications that move physical specimens in the field to squiggles on a page to graphs and equations that can be shared with and interpreted by other scientists” (McGinn & Roth, 1999, p. 20). The practice of using representations in a cross-disciplinary inquiry into defining something unknown, however, may also bear resemblance to processes in other professions. Professions involving design or innovation processes are examples of areas where elements of these competences are central. The processes, which often involve defining and developing something unknown, draw on complex systems of knowledge from many areas of life, and the creativity involved in visualizing the undefined object has to be part of the creative use of tools for supporting the object defining processes. Tools for innovation processes are numerous and include mind maps, which bear resemblance to some of the representations seen in this thesis, or sketching tools such as the ones used by industrial designers, software engineers, usability engineers, etc. (Buxton, 2007). The conclusion of this part of the discussion is thus that the competences used for doing representational inquiry are valuable and central in the context of science education as well as in the context of professional scientific practice and professions involving creative innovation processes.

The definitions of representational inquiry competences enacted in the learning environment of the game *Homicide* contribute to the field of learning game research by supporting existing definitions
of epistemic games or games simulating elements of professions as environments which support innovative thinking (Shaffer, 2007). The findings in this thesis further contributes to the field by qualifying definitions and specific understandings of what competences are enacted in game-based learning environments that simulate professional science practice. Future studies should be done into understanding the characteristics of these competences and the environments they are enacted in. One perspective to be considered in future studies is determining whether representational inquiry competences are specifically related to game-based environments. Toward the end of this chapter, I return to a discussion of the possible future set up of game studies.

10.2: Overlapping networks of representational inquiry

Part III of this thesis was devoted to answering the research question of how inquiry representations, representational inquiry competences and learning were enacted in networks of entities in the classes playing the game *Homicide*. In Chapter 7 I studied how inquiry representations took part in inquiry and learning processes in the various classes. I argued that inquiry representations can be understood as mediating artifacts which connect the students and the task of solving the case. Inquiry representations mediate this process by allowing the representational states of game elements to be coordinated in the media of the representation, i.e. the drawing or the board. By comparing situations of representational inquiry in *Class A* and *B*, I showed that the different formats of inquiry representations in the two groups, due to their structure and inclusion or exclusion of representational states of game elements, act as mediating artifacts in different phases of the inquiry. It was presented how transformations of representations were an integrated part of inquiry in *Group B1*. I argued that student learning concerning their case and knowledge construction takes place as a reorganization of representational structures.

In Chapter 8, I further investigated the transformations, or mutability, of representations in phases of inquiry in the classes. The conclusion reached in this investigation was that the inquiry representations acted as a mutable actor with different identities enacted in networks of fluent student relations and practices. Nevertheless, it also became clear how the different identities did more than just change in the course of the investigation in the individual classes. The entity, which can be characterized as an inquiry representation, could be understood as an entity enacted with different identities across classes as an effect of the fluent representational inquiry practices and strategies. This enactment of different versions of inquiry representations of the related representational inquiry competences was further investigated in Chapter 9. In this chapter I attempted to understand the different versions of inquiry representations in terms of the patterns of related actors and practices in the particular network of classes playing the game *Homicide*. I
argued that the construction and shape of inquiry representations depend on patterns of related actors such as teachers, computers and the fictional portrayal of the police profession. It was argued that these networks enact inquiry representations in a variety of shapes and designs and with different functional foci. It was concluded that more than just different versions of inquiry representations appear in particular networks of actors, for example, the competences that go into conducting inquiry by creating representational structures. The students’ representational inquiry competences are thus also enacted in different versions in the networks of entities in the particular setting the game *Homicide* is played in.

In this thesis, the competences, inquiry representations and learning enacted in the game *Homicide* have been analyzed as a complex object with many coexisting identities (Mol, 2002). By drawing on various theoretical perspectives, the analyses of the various situations have generated several answers to the research questions of what is enacted and how it is enacted in the game *Homicide*. Inquiry representations are the materializations of translations of cases, the mediating objects in the shifting phases of representational inquiry processes and changes as students gain knowledge about the case and, finally, they are mutable actors. In the following, I discuss overlapping relations, effects or practices of the various identities of inquiry representations (Gad & Jensen, 2007).

Throughout this thesis I have argued that the variety of formats is different versions of the inquiry representation and not unrelated different objects. Inquiry representations are enacted as materializations of the undefined cases during presentations in both *Class A* and *B* and mediate theory-evidence coordination and the construction of hypotheses in inquiry processes in both classes. However, they mediate different phases of inquiry due to their different materializations. Below, figure 10.1 illustrates how different versions of inquiry representations and representational inquiry competences can be understood as enacted in networks of actors in the various classes playing the game.
The understanding of how inquiry representations are enacted and mediate representational inquiry in the particular classes is central in the future development of the game *Homicide* and other similar game-based learning environments. In Chapter 6 it was discussed how a lack of metarepresentational reflection existed in the classes studied at the level where students are able to evaluate representational inquiry strategies and formats. Chapter 8 presented situations from an interview done in *Class B* after the game was over. The focus of this interview was to understand the students’ motivation and criteria for constructing, using, and transforming inquiry representations. Chapter 8 showed how students of *Class B*, when presented with *Pictures* of the representations constructed by *Class A*, were able to evaluate the advantages and disadvantages of the different formats. They also defined central criteria for their format, for example, the inclusion of details about characters and clues, and keeping enough space for extending the representation.
with new information. When a relation between the particular networks of representational inquiry is made (see arrow in figure 10.1), students were able to meta-reflect on their own and others representations. This method for connecting classes is an aspect that can be explored in the future development of the game environment. Part III also showed how different representational formats mediate different phases of inquiry. Presenting various representational to the classes playing the game would permit student reflection on how different formats can be combined to mediate inquiry in different phases.

Another perspective from which to look at overlapping relations, effects and practices of the different versions of inquiry representations is to try and understand what characterizes the learning processes enacted in the different classes. If we treat the concept of learning in the same manner as we have treated inquiry representations and competences, we need to ask what learning is enacted as opposed to what is learned (Sørensen, forthcoming). In Chapter 6 I reached the conclusion that the various versions of inquiry representations act as mediating artifacts in different phases of the inquiry process. The nature of the object of inquiry representations, however, differs in central ways from the mediating objects described by Hutchins, such as formal procedures or charts. The most fundamental difference is that the inquiry representations were constructed in the initial phase of the inquiry and transformed in an integrated process of students generating knowledge about their case. Hence, inquiry representations are also a materialization of the students’ knowledge at a specific time in the inquiry process and thus, as the game progressed, a materialization of the knowledge students gained in relation to the case. In her book, The Materiality of Learning, Estrid Sørensen defines learning in relation to materiality (Sørensen, forthcoming). For Sørensen, materiality refers to the achieved quality of an entity that allows it to relate to other entities. Describing materiality is thus to describe how something gets related to something else. Sørensen defines learning as growth in knowledge. ‘The materiality of learning’ is thus defined as the achieved ability of a growth in knowledge to connect to other entities. Using this perspective, Sørensen states that learning is not situated but extends to also include the places where what is learned is practiced.

The development of Homicide was, as described, initially inspired by the notion of situated learning. The empirical studies of the game, however, show that the network that representational inquiry competences and learning processes are enacted in extends beyond the game and school context to include various entities such as poster boards, police fiction and game complexity. Questions for future studies can thus involve how we understand the situatedness of learning in relation to the conclusions made in this thesis or they can consider whether we need to rethink situated learning.
in relation to game-based learning environments. It is beyond the scope of this thesis to explore the concepts behind these questions, but an exploration of the materialization of student learning in the game *Homicide* (and in learning games in general) as an aspect of 'materiality of learning' is an exciting perspective for future studies.

10.3: Methodological and theoretical discussion and perspectives for future studies
This thesis is empirically grounded in DBR studies of the game *Homicide*. In this section, I first discuss how the DBR approach has contributed to the study of the game and what implications the conclusions presented have for future studies of the game *Homicide*. This thesis also presents an attempt to apply elements of theoretical and methodological network approaches to a new area: learning game research. In the last section I discuss the implications of choosing this approach for the outcome of the current studies. This discussion concludes with more general discussion of what the ANT methodological approach can contribute to the area of learning game studies and development.

**Methodological discussion: Defining future DBR studies**
The scope of this thesis has been ethnographic studies of what competences and practices are enacted in the learning game *Homicide*. I have defined elements in this type of game environment which can hopefully contribute to a greater understanding of learning in game environments in the field of learning game research. This thesis has fulfilled the goal of building strong hypotheses about what competences, practices and tools are enacted as part of certain practices in certain networks of actors. Having met these goals directs the focus of future studies to include a further definition of elements of representational inquiry competences, such as elements of meta-representational inquiry competences, and how they are enacted in *Homicide* and other game-based learning environments.

There are several possible approaches that can be taken in future studies. Regarding the game developers’ approach, it would be relevant to ask whether developing technologies or scenarios which support student work with the relevant practices is possible. This thesis demonstrates how different versions of inquiry representations mediate different phases of inquiry. Consequently, one future approach that can be taken would be to develop templates or technologies with the objective of combining the different versions of relational-focused inquiry representations and transformation-focused representations to support students’ representational inquiry throughout the different phases of inquiry. This thesis focuses on how students enact competences in *Homicide*. Future studies could be directed at understanding the ability to use the competences in a
changed setting in *Homicide* or in another context. This would traditionally be studied as whether students are able to transfer the competences to another setting as proof of what they have learned.

These ideas concerning future studies contain interesting perspectives. In light of the conclusions in this study, though, I would chose to approach both types of studies differently. In this thesis I have shown how inquiry representations are enacted in networks of actors and changing practices. The network patterns influence the initial construction, shaping and transformations of specific versions of inquiry representations. In designing setups for future studies on understanding new elements of the representational competences enacted in *Homicide* or their enactment in other settings, I believe that it is necessary to think in terms of making the entities that have shown agency in these studies available. If we define further studies in terms of making entities available, then DBR is an essential frame in this process. The concluding hypotheses in this thesis on influential entities in construction of versions of inquiry representations and the enactment of competences can guide the initial design process in future studies. Whether the same entities prove to be actors in the enactment of representations in new settings can only be determined by studying the particular setting. I thus argue that the DBR methodological frame is key when using an ANT approach to game-based learning environment development. If we believe that competences and tools are effects of networks in the classes playing the game, then we need to do iterative studies of these networks in order to know what is enacted and what we have designed for.

As discussed in Chapter 3 there are, however, challenges and pitfalls involved in using the DBR framework in learning game development and studies. The environments developed are based on conjectures made during the design phase. These conjectures guide the initial studies of the game, but they should not work as obstacles to understanding what is enacted in the particular setting the game is played in. In this thesis, I used the framework of DBR for combining and integrating various research methods at different phases of research and development. Upon entering the analysis phase, I applied an ANT-inspired methodological approach. This process meant moving from constructing a design based on theories and conjectures first, and then taking it apart in the analytical phase. Carefully constructing a framework based on theories of learning and on conjectures on how to turn these theories into action in a learning environment only to then deconstruct them using a crude ANT methodology that ignores conjectures build into the design may seem counterproductive. This thesis shows, however, that the constructing-deconstruction process brings new aspects to the theories that were the initial inspiration for the game design. Studying learning in networks has thus resulted in reflections on the situatedness of learning in a
game-based environment such as *Homicide*. I have not, however, pursued complete deconstruction but have maintained the empirical focus on the representational practices established in the development and data generation phases.

Another pitfall which has been discussed in this thesis is the balance between design and theory generation. As described in this thesis, DBR processes can lead to unbalanced processes between development and theory generation, as was the case in the initial *Homicide* studies. These problems should guide continued discussions and definitions of DBR methodological concepts. Still, I believe that the DBR process allows a deepening of the understanding of new practices through the processes of implementation of theory in design via continuous cycles of design and analysis. The following outline proposed for future studies is thus discussed in terms of design experiments that can be integrated into the game based on knowledge generated in this thesis. I propose a variety of types of implementation but whether they are effective or not will have to be tested in the particular settings with the students playing *Homicide*.

How should the game be set up in future studies to gain a deeper understanding of the different elements of representational inquiry competences and the environments they are enacted in? To answer this, I will briefly return to a discussion of the design experiments I made in the various classes playing *Homicide* and what the conclusion that can be made from them are in relation to a future set up of the game. In each of the classes studied, I chose not to encourage or ask the teacher to encourage students to use representations in their work during the game. This was to gain an understanding of both whether students would use representations in their work and how and what elements influenced their work. I was also concerned that the teachers’ role would dominate the situation, possibly leading to students being unable to create their own formats and methods. I believe that this strategy led to situations allowing me to identify a network of different actors as opposed to direct studies on student-teacher interaction. In a future setup of the game, I would experiment with making entities which have proven to be influential in the construction and shaping of inquiry representations available, such as boards, paper and teacher recognition. For future studies, I would thus encourage – or instruct teachers to encourage – students to make use of boards or paper for constructing representations as part of their work. This implies of course that the right conditions for this work exist in the room where the game is to be played. Display boards, white boards and poster-size paper should be available to students and they should be encouraged to use them. I think it is important that students are put in a situation where they are able to invent their own formats of inquiry representations to be able to create ownership of the representation and for it to support their specific inquiry process. The teacher should thus not
instruct students to construct certain formats but simply make the media we have seen used for the different versions of inquiry representations available. One issue that has been discussed throughout the thesis is the lack of student meta-reflection in the construction and use of inquiry representations. One aspect to focus on in future studies would be to create situations which would support student meta-reflections on representational inquiry strategies. The relation I established between different versions of representational inquiry proved to be an opening for student meta-reflection concerning theirs and others’ strategies and criteria for using representations for doing inquiry. This relation could further be explored and developed as a post-game session where the nature of the criminal case as an object of investigation is discussed as well as the students’ representational inquiry strategies.

Finally it is important to mention that there are several other aspects of the complex empirical field of the game Homicide that can be explored in future studies. Teacher roles in this type of game are one aspect that I would have liked to explore further if I had had another three years to do research. Because this is not possible, I have included a paper in the appendix of this thesis based on the observations I made of teacher roles when playing Homicide in Class D, the forth class I observed while collecting data (Magnussen, 2007b).

**Theoretical and methodological reflections: Why use ANT in learning game studies?**

In the analytical part of this thesis I have used various methodological and theoretical lenses to understand a variety of complex aspects of the actions observed in *Homicide*. The different pathways to understanding the phenomena studied can perhaps create the image of a split personality, but I believe that they tell important stories about what games such as *Homicide* can contribute to school education. In the following I discuss the theoretical and methodological approaches in this thesis and what the approaches might contribute to the area of learning game studies.

Part II drew on the different theoretical perspectives of representational and inquiry practice in schools and scientific professions. The objective of the studies was to understand elements of the new practice observed, and I believe that the various approaches complimented one another in defining this practice. This resulted in a definition of representational inquiry competences that attest to practices in and outside school. By drawing on theories of inscriptions as tools in the construction of scientific facts (Latour, 1990), individual representational competences (diSessa & Sherin, 2000), and individual inquiry processes (Kuhn, 2005), the definition of representational inquiry competences address the nature of inquiry representation constructed and the student
competences for doing so. The approaches do not, however, provide normative evaluations of whether these competences are valuable competences which belong in school. To evaluate this we need other standards such as curriculum descriptions and descriptions of epistemologies of scientific practice and practices of other professions which were applied earlier in this chapter. The underlying conclusion made in this section was that if considered central in school education and scientific and other professional practices, representational inquiry should be an integrated part of education in schools and the game is thus valuable. This theme can, however, be debated just as it has been in the field of science didactics concerned with the discussion of scientific literacy (Andersen, et al. 2004).

Inspired by the ANT concept of general symmetry and concepts of distributed cognition, Part III presented an examination of agency in networks of human and non-human actors. Looking through the ANT lens at worlds such as students playing learning games in school makes visible, however, the extensive networks of related actors. Questions and discussions of where studies of networks end must be an evitable part of any ANT study. Studies on these networks are not an exhaustive study of the extensive networks mapped in Chapter 9. Introduced relatively late in the three-year PhD project, applying the ANT methodology can be taken much further in future studies than it was here. As mentioned earlier one future direction to take involves understanding student representational practices in terms of the materialization of knowledge and learning. The strengths of the ANT methodology are, however, that they do not impose the reductions of classic social theory (micro/macro, human/non-human) or the area studied (game/real world), but expose the researcher’s reductions of networks studied.

The exclusion of classical reductions is, I believe, a central contribution of ANT when applied to learning game research. Game studies and educational or learning game studies have been criticized for having an essentialist perspective where games are understood as self-confined entities or for having a determinist perspective which seeks to document the value of specific game designs (Hanghøj, 2008). Both perspectives are problematic as they do not take the messy interaction in the educational setting into account. The argument made here is that understanding practice, tools or competences as an effect of a network in a particular setting can help us avoid the assumptions made by both the essentialist and the determinist. Entering these settings with a principle of general symmetry guides us to follow the actors and look for agency while disregarding assumptions about intrinsic qualities of design or whether agency should take place with or without computers or in or outside classrooms, or whether the actors are students, teachers, elements of the design or tools enacted in the networks of each of these. Instead of addressing games and new
learning technologies in terms of narrow definitions, we need to borrow or develop new, perhaps less sophisticated, terms such as ‘mediators’ or ‘versions’ to describe generalized learning game traits. I believe that this radically different perspective on game studies can contribute new understandings of play and learning in school contexts.
REFERENCES


ABSTRACT
Using learning games in education gives rise to a learning situation where game culture meets school culture and the result can be successful or corrupting for both. In this paper I present a case study of school classes and their teachers playing the game ‘Homicide’, a game where children play the roles as forensic experts who solve a series of murder cases. When teachers use this type of games, they have to adapt to new teaching situations and roles. This includes the fictional role in a game, but also the role as a supervisor for a group of students that play the role as professional experts. I present examples of teachers who adopt different roles in the game, and discuss how understanding the background for these roles can help us define the game-based learning situation. Finally I discuss what consequences the problems presented here may have for the design of future learning games.

Author Keywords
Learning games, science education, teacher roles.

INTRODUCTION
In recent years, research institutions have been a test-bed for development of a new type of game, a generation of games that simulate professional practice. These games are created to bring a practice situated in a professional setting into schools. Internationally, there are several examples of this type of learning games that have been developed at universities and are currently used in schools [4, 8, 5]. This type of games has been defined as ‘Epistemic games’ by David W. Shaffer [7]. Each profession has its own knowledge, values and skills - its ‘epistemic frame’. The game media gives us a way to simulate these ways of seeing the world. The goal with these games, where children role-play professions to learn professional ways of knowing, are that children learn to solve problems in the real world and how to be innovative within a profession.

But what happens when these games meet school practice? This is the overall theme of the larger study this paper is based on; to understand what happens when this class of games becomes situated in schools, and to understand what emerges out of this meeting. The case study involves school classes and their teachers playing the game Homicide, a game where children role-play as forensic experts who solve a series of murders. It is a complex situation, and when we design and evaluate the game, we have to understand the different practices that come into play in the learning situation: There is the professional practice we are trying to simulate, the school practice it is placed in and there is the game practice that frames it all. All these domains have values, rules and demands for the play and learning situation and we have to understand in
what sense these practices are present in different
game learning situations.

This paper presents examples of roles adopted by
teachers playing the game. When teachers use
profession simulation games in their education,
they have to get used to new roles. This can be
the fictional role they play in the game or the role
they come to play in the class as a supervisor for
a group of expert students who essentially have
more detailed knowledge than the teacher on the
game subject. I present two different examples of
student - teacher interaction in the game
Homicide and discuss the different domains that
play together or against each other when this class
of games enters school.

THE GAME HOMICIDE AND HOW THE
TEACHER ROLE WAS INTENDED

Homicide is an IT-supported game where players
role-play forensic experts. It was developed by a
game development group at Learning Lab
Denmark (the author of this paper was a member)
and was published by the Danish school book
publisher Malling Beck. The game takes one
week to play through, from eight in the morning
to one or two in the afternoon for five days. It is
organized as a combination of work in
investigative groups (each working on their
individual case) and meetings where groups share
information about their cases and are encouraged
by the chief of police - the teacher - to set new
goals in their investigation. After each meeting,
the teacher makes new parts of the game
accessible on the computer, which gives the
investigators new information to work with. The
game ends with the groups presenting their
theories to the other teams and writing an
indictment based on the evidence and testimonies
of suspects and witnesses. The interaction in the
game is primarily between the students in the
classroom and not a computer-student interaction
as in most computer games. Instead the computer
is used as an extended police database.

The game’s interface provide the players access
to videotaped interviews with 'suspects', reports
from the local police, maps and pictures of and
information about evidence found at the crime
scene. With this information at hand the players
have to plan their investigation process. The
investigators analyze the evidence through
laboratory work and analytical processes using
technological and scientific, theoretical and
practical methods that are available in the
Forensic Handbook which is part of the data base.
Some of this work is pen and paper tasks and
some practical analysis in the school laboratories.
The laboratory work includes chemical analyses
of samples from a suspect’s hands to determine
whether that person has gunshot residue on his or
her hands, which would indicate that the suspect
has fired a gun lately; and measurements of
shooting angles to determine the height of the
shooter. The students have to handle different
types of data and use different skills, including
critical thinking when they analyze interviews
with the suspects and empirical competencies in
handling the data from the technical
investigations.

The educational goals of the game are closely
integrated with the fictional investigation process.
The overall goal for cross-disciplinary science
learning in the game is that the game should
support working with, and learning of, the
process of inquiry as the basis of scientific
investigation. The process contains different
steps: problem definition, establishing
hypotheses, conducting investigations, making
observations, collecting data and explaining
results. The methods used to solve the murders,
e.g. fingerprint technique are as close to the real

![Figure1: Homicide, Interface the policeman’s desk.](image-url)
forensic professional methods used by forensic experts as was possible. The students have, of course, seen movies and read about police work, and getting a chance to use the professional tools are meant to further their motivation.

In the manual the teacher’s role is primarily defined as a helper and initiator. The teacher has access to all the answers and should advise students by asking open questions that will help players focus and get back on track if they get stuck in the investigation process. The pupils can get the data they need from the ‘police database’ but the teacher is still in control of what is released at what point in the game. In the manual, the teacher is also encouraged to role-play the chief of investigation who advice the investigators, but let them take the decisions. The chief sets the agenda at the status meetings where all the groups reports to each other and he or she asks critical questions about the further investigation. The teachers should work on striking a balance where they play roles to a degree that feels natural to them instead of not playing roles at all. In the manual, the teachers are reminded that it can be disrupting for the pupils’ identification with their roles in the game if they have to step out of the role in the game and into the ‘pupils’ role whenever they speak to the teacher. In the manual it is stressed that it is important to maintain the illusion throughout the game that the pupils are doing something important in solving the cases, this keeps up motivation for conducting the investigation process.

We received several comments about the teacher manual while we worked with different groups of teachers. In comparison with traditional school books and other materials sold by the publisher, the IT-supported role-playing game is a novelty to many teachers. The teacher therefore expressed a need for a quick overview of the game situation that the teachers’ manual did not provide.

Before we initiated the game test, the author of this paper therefore used one or two three-hour sessions with the teachers after they have had a chance to study the game manual. The teachers were both introduced to the technical side of the game (the student and the teacher interface) but also to the role of the teacher and how he or she was expected to role-play as chief of investigation. References to fictional characters form the Danish TV series Rejseholdet and the American show CSI were used as concrete examples of police characters that serve as role models. The teachers were also encouraged to set up working spaces for each group to use for their investigation process. During the game week the observing researcher did some coaching on IT issues, the running of the game and made suggestions about where and how to run status meetings.

TEACHERS’ ROLES IN HOMICIDE

The study presented here is based on a larger study of four different school classes with different teachers who played Homicide. It is based on five full weeks of full-time video observations - around 120 hours of film (in one of the classes there were two researchers filming) in total. The students in the classes were from 13 – 15 years old. Apart from the video observations, group interviews were done in all the classes with students and teachers and pre- and post tests of how the game broadens the students’ understanding of the police inquiry process. This study is also based on the diagrams and log books the students produced during the game.

The following examples from a set of observations of a 7th grade school class who played the game over a full school week. The observations were conducted by the author of this paper and a research assistant. In this class the game was run by two teachers, a male science teacher and a female Danish teacher. These examples of contrasting approaches have been chosen because they illustrate the problems that arise when teachers changes roles in the game. These are also example of approaches to the game-learning situation I (more or less explicitly) have observed in all the school classes that I have done observations in. I believe that understanding the background for the teacher-student interaction and the problems it creates will provide us important clues to defining the learning situation in this class of games.
This first example is from a situation where the male science teacher helped a pupil to take fingerprints. The class was midway through the game. They were on a level where they had to analyze traces like fingerprints, DNA in blood or gunshot residues from the hands of the suspects. In the specific situation, the groups had just received some objects such as a CD cover and a hammer in professional-looking plastic bags that they had to analyze for fingerprints. The fingerprint analysis is a special feature in the game design. It is of course impossible for the students to analyze real fingerprints from the characters as we would then have to call in the actors who play them every time a school buys and plays Homicide. Instead, the game is designed to let the teacher secretly place a fingerprint on the object. The teacher is then instructed to collect the fingerprints after they have been lifted by the pupils. He then secretly ticks off the task on the teacher interface and a scanned fingerprint appears on the pupil's interfaces where they can compare to the suspect's fingerprints to find a match. The specific objects - like the hammer - are described in the case file as a possible murder weapon. The analysis of the fingerprints on it may provide central clues to who committed the murder in the specific case. The pupils use genuine professional tools such as powder, brush and film to lift the fingerprint off the object. In the specific situation, members of two groups were standing and sitting around a table in the common area where the workstations were. Two members – a girl and a boy – from different groups were using a brush to apply powder to the objects they had received from the teacher. There were a lot of children from the different groups around the table. These were the first two groups who were lifting fingerprints and members from all groups were interested in how it is done. The girl (girl1) had just finished brushing a hammer that she believed was the murder weapon. The fingerprints she was supposed to lift was not clear. In this example she was asking the teacher Thomas to take a look at the hammer she was testing for fingerprints. Thomas came over and stood beside her while they talked.

Girl 1: Thomas could you come over here, please?
Thomas: Yes
Girl 1: I don’t think this is clear. I can’t even see it.
Girl 1: You can see theirs’ (their fingerprints) (points to the CD the other boy at the table is testing for fingerprints)
Thomas: Try this instead, I know that… (low-voiced, inaudible)
Girl 1: That’s not ours
Thomas: No, I know. It’s some extra things I have if it didn’t work.
Girl 1 uncomprehending takes the plastic bag he gives her.
Another girl (Girl 2) has been following the conversation between Thomas and Girl 1.
Girl 2 to Thomas: But what will that help?
Thomas: The point here is that you must practice lifting fingerprints off objects.
Girl 1: Should I just try here again? (she points to the hammer.)
Thomas: Yes, try again, but if you don’t find anything, then try those (point to the objects he has just given her).
Girl 1: Yes, then I’ll try those.
Thomas: Try and look at those too. (The objects he has given her.)
Girl 1: But this is not some of the things we get? Thomas: No

Girl1 kept brushing powder on the hammer, but after a while she started testing a black disk - one of the new things that the teacher had given her. Two girls from another group were waiting at the table for Girl 1 to finish. When she was almost finished, they started to discuss what to do. One of the girls asked how it is possible to find out whether it is a suspect’s fingerprint. She was told by the other girls that she can not find the murder by using the fingerprint, because it was not the real fingerprints. Another girl who is confused with the explanation asks what the print then can be used for. She is told that she had to give the print to Thomas, who would then give her some more information.

In the example, it is clear that the teacher undermines the game on different levels, and that
this has a clear impact on the student’s engagement. If the teacher had told a student in a non-game-based science class that practicing a technique was more important than the result itself, it would possibly not have caused the same confusion as we can see in the above example. But why is this? In answering this question it might help to try and understand the different levels in the game-learning situation in this type of games.

From the game perspective, it is interesting to note the immediate response to Thomas’ actions. There is no doubt that students aged 13 are fully aware that they are playing a game and not solving four real murder cases. But still the role-play creates a space where it makes no sense to girl 1 and 2 (who observes the situation between Thomas and girl1) to test objects that play no role in the game narrative. Their confusion and questions lead the teacher to explain his perspective on their work: that practicing fingerprint technique that is the important part of what they are doing and not the results of the technical analysis.

It is quite understandable how this conclusion makes sense to Thomas. The fingerprint is not used for any further analysis. After lifting the fingerprint, the students print out a scanned fingerprint that is used in the further comparison with suspect’s fingerprints. With this background knowledge it is clear why Thomas come to the conclusion that the process and not the result is important. In the game material, teachers are both instructed (as described above) in their overall role as chief of investigation, and also to provide students clues that resemble the objects on the pictures from the crime scene, e.g. the same brand of hammer as on the picture. The possible pedagogical background for Thomas’ approach will be discussed later in this paper. From a game culture perspective, the students’ confusion might come from a change of the basic game mechanics. The basic rules in Homicide are that all the things from the crime scene that are made available to the players could potentially provide them with important clues to who committed the murder. If they do a thorough analysis of these things and the interviews with the suspects, they will eventually be able to put the collected pieces together and solve the puzzle of who committed the murder. In this context it clearly makes no sense to the students when Thomas tell girl 1 to do fingerprint analysis on a disk that that is not described in the case file as an object found at the crime scene. When he furthermore tells her that the fingerprints she is in the process of lifting are unimportant, he breaks the basic rules of the game.

The teacher might not be aware of how changing the game rules breaks the pupils’ illusion that they conduct important actions in the classroom context. This can be seen as breaking ‘The magic circle of the game’ (Salen & Zimmerman, 2004). The magic circle of a game is defined by Salen and Zimmerman as ‘the space within which a game takes place.’ (Salen & Zimmerman, 2004). In this definition, the magic circle is created whenever players decide to play a game. They can step into a formalized circle with set rules (like backgammon) or they can create their own magical circle (like arm wrestling). The circle is the boundary of the game space where the rules of the game have authority. In this space game objects obtain special meanings: ‘Within the magic circle, special meanings accrue and cluster around objects and behaviors. In effect, a new reality is created, defined by the rules of the game and inhabited by its players. Before a game of Chutes and ladders starts, it’s just a board, some plastic pieces, and a die. But once the game begins, everything changes. Suddenly the materials represents something quite specific. This plastic token is you. These rules tell you how to roll the die and move. Suddenly it matters very much which plastic token reaches the end first.’ p. 96 [6].

The group of girls in the situation might thus be well aware that they are not solving real murder cases, but they have on some level agreed to step into the magic circle of the game and become police investigators. The reaction of confusion and disbelief from the group of girls could illustrate that the magic circle of Homicide and the meanings it gives objects like fingerprints make the situation meaningful to the girls.
Breaking the circle makes their actions meaningless as the example illustrates. This next example is from the same class where the other teacher in the team, Anna, helped another group. In this situation, the group was on the final stage of their investigation and they were comparing the data they had to find the crown suspect. In this example the teacher were discussing the case with the pupils in their workspace where they had put pictures and papers with test results on boards.

Anna: How firm is your evidence?
Boy 1: His (Preben – the crown suspect) fingerprints are on the hammer.
Anna: The hammer that killed him (Adam the victim)?
Boy 1: Yes.
Anna: Yes.
Boy 1: And he (Preben) has a shirt with blood on.
Anna: Blood from Adam too?
Boy 1: Yes.
Boy 2: And he has a reason for killing him because his 15 year-old daughter is pregnant with Adam’s child.
Girl 1: He didn’t know.
Anna: He didn’t know?
Boy 1: No. It’s a motive
Anna: Do you think that that would be enough to get him convicted?
Boy 1: And he doesn’t have an alibi.
Anna: What was that?
Boy 1: He doesn’t have an alibi
Anna: Have you spoken to him?
Both boys: Yes
Anna: After you have found out about this?
Girl 1: No
Boy 1: No they are (pointing to the girls working at the computer) doing that now.
Anna: Maybe it would be good to confront him with the new evidence and hear what he has to say about that, right? Okay, and then I think you should spend a little time to find out if the evidence you have is good enough. Is it valid in court? And if you agree that it is then you have to try and reconstruct the crime based on your data and from what you can work out yourself. That’s the next thing, right?

Anna leaves and the two boys get into a long discussion on what the evidence points to. The teacher Anna guides the pupils through the analysis by asking open questions. Even though Anna is not directly role-playing the chief of investigation, her focus is on the ‘professional’ work of solving the case. With questions such as ‘have you spoken to him?’ she refers to actions that are done on the computer in the game as if the students were actually confronting the suspect in person. This rhetorical trick makes actions in the game seem more ‘real’. Anna’s focus on whether the clues the students have will be enough to get the main suspect convicted also shows that her success criteria are in line with the game goals. It thus seems that she stays in the magic circle of the game by using terms and expressing the same goals as what was intended in the professional role. This also seems in line with the students understanding of the situation and creates a constructive teaching situation where students are helped to continue the inquiry process after the supervision.

DISCUSSION
In this paper I have presented two different teachers approaches to the game learning situation. It is essential to understand the background for these teacher roles to define what is specific about the game based learning space in these games.

In the example with the teacher Anna, the roles between teacher and pupils are quite different from the first example. At the end of the game, the children are experts on their case, and Anna is the chief or supervisor that might not know (or appears not to know) all the details of the case, but supervise the investigators in constructing a strong case from the knowledge they have. This solidifies roles of knowledgeable experts and the supervising teacher or chief investigator.

In the example with Thomas, we see a different approach to the learning situation. Telling students that practicing the fingerprinting technique is important and not the result, Thomas expresses a well known understanding of learning that is seen in many schools today: That the technique can be learned out of context and then...
be transferred and applied by the student to another setting. What fails to make sense for the students in the game situation possibly makes perfect sense in a school context. If the situation with Thomas and girl1 had happened in an everyday science class, it possibly would not have caused the same kind of confusion, because in many schools science is learned out of context of the domain of knowledge that it is part of. This is what James Paul Gee calls the “content fetish”:

‘The content fetish is the view that any academic area, whether physics, sociology, or history, is composed of a set of facts or a body of information and that the way of learning should work is through teaching and testing such facts and information’
[1], p. 1.

Out of context, the meaningful and understandable goal that the profession simulation game creates – that students do scientific analysis to solve the mystery of who committed the murder – disappears. In this class of games this is closely connected to the simulation of the profession or domain of knowledge. As James Paul Gee defines it:

‘Any actual domain of knowledge, academic or not, is first and foremost a set of activities (special ways of acting and interacting so as to produce and use knowledge) and experiences (special ways of seeing, valuing, and being in the world). Physicists do physics. They talk physics. And when they are being physicists, they see and value the world in a different way than do non-physicists.’
[1], p.1

Learning situations with clear meaningful goals where the challenges lie in understanding how to reach the goal are specific to games. In this type of games these qualities are ‘married’ to the professional learning-by-doing approach. The professional simulation game Homicide simulates this domain of knowledge - the way the police investigator sees and understands the world. The investigators are primarily focused on results and only on process to the extent that it has to be precise and thorough to get good results. When Thomas tells students that the process is important and not the result it is not just the magic circle of play he breaks. The meaningful goals of learning within the domain of knowledge also disappear.

Should we then focus on developing games for out-of-school-settings to avoid the corrupting situations described in this paper? As we have seen there are teachers that can take on the advisor role both as part of a game fiction and as the professional teacher. Here both teachers and pupils take on other identities in the profession they role-play and solve professional problems both parts might not know the solution to. The teacher becomes the professional leader that might not know all cases or projects of the team but advises groups using a toolkit of perspectives and values within the profession they role-play. The pupil becomes the expert in a specific case which also gives her the role as competent problem solver in the specific project. In these games focus is thus not only on the content or product, but also on the professional roles the participants take on and the form of collaboration. I believe that by designing and testing these games in schools we as researchers and developers can learn something from the professionally competent teachers who master combining fictional roles with teaching students deep understanding of a subject. This might is also a cultural problem. The Danish schools are not yet as test-based as the American schools and teachers still have room for experimenting with new teaching forms.

The intention with this paper has been to use situations with the professional simulation game Homicide to understand what happens when this type of games becomes situated in schools. A deeper understanding of the background for the teachers’ roles will provide us with valuable elements for a definition of learning in this class of games. This will also give us an understanding of how to introduce teachers to this teaching form and how to develop new types of games.
REFERENCES


Paper reference: