Mentor Modeling: The internalization of modeled professional thinking in an epistemic game

Abstract: Players of *epistemic games*--computer games that simulate professional practica—have been shown to develop epistemic frames: a profession's particular way of seeing and solving problems. This study examines the interactions between players and mentors in one epistemic game, Urban Science. Using a new method called *epistemic network analysis*, we explore how players develop epistemic frames through playing the game. Our results show that players imitate and internalize the professional way of thinking that the mentors model, suggesting that mentors can effectively model epistemic frames, and that epistemic network analysis is a useful way to chart the development of learning through mentoring relationships.

Introduction

There is a broad consensus that mentoring is an important part of young people's intellectual, social, and emotional development (Freedman, 1999). In this paper, we look at one powerful form of mentoring—the mentoring that takes place in professional training—and examine how one feature of professional mentoring—modeling— can be used to help players in a computer game learn real-world skills, knowledge, values, and ways of thinking. The context for this study is the epistemic game Urban Science, a game modeled on a practicum course for graduate urban planning students (Shaffer, 2006b). Epistemic games are computer-based role-playing games that simulate professional training.

A critical element of professional practica is the interaction between young professionals and their mentors (Schön, 1983, 1987). In the urban planning practicum, students meet regularly with planning consultants: experienced professionals with whom the students talk about their work. These reflective conversations play a critical role in developing a professional way of thinking. In Urban Science, mentors--who are also called planning consultants--do the same for the players. As in the planning practicum, planning consultants in Urban Science help novices with the intricacies of the work, provide feedback, and inspire them when they are stuck.

A central role of professional mentors, however, is to model the way of thinking that is unique to their profession: what Shaffer (2006a) calls the epistemic frame. This paper looks at whether this same form of mentoring takes place in one epistemic game, and if so, whether it has the same effect as mentoring in the professional context. We ask to what extent players in an epistemic game imitate the epistemic frame that in-game mentors model, and whether this imitation leads to the internalization of a professional way of thinking. While the results are specific to this study, the type of mentoring and learning that happens in epistemic games could be useful models for designing new types of educational settings, in schools or elsewhere.

Theory

There is a wide body of research on mentoring and its effects on youth development that focuses on the role that mentors can play in promoting positive behavior and habits in youth (DuBois & Silverthorn, 2005). In terms of cognitive development, Vygotsky (1978) is important for his work on how the development of the child's higher cognitive processes depends on the presence of mediating agents in the child's social learning environment. While Vygotsky himself "emphasized symbolic tools-mediators appropriated by children in the context of particular sociocultural activities, the most important of which he considered formal schooling" (Kozulin, 2003), scholars have extended the discussion of those mediating agents to emphasize mediation through another human being. Much of the literature on social mediation is concerned with how adults can facilitate the child's problem solving process by arranging and structuring the problem for them, and by participating in the problem-solving itself. Joint problem solving (Wertsch, 1978) and other situations where a child's current capabilities are extended through the support of an adult, are often framed as "scaffolded" learning (Wood, 1999) or as cognitive apprenticeship (Rogoff, 1990). Mediating strategies like scaffolding, while perhaps too context-dependent and numerous to be simply classified (Kozulin, 2003), have been well described (Schaffer, 1996), but how particular aspects of social mediation contribute to a child's cognitive development is unclear. How social learning processes are converted into internal developmental processes Vygotsky leaves murky, suggesting that showing "how external knowledge and abilities in children become internalized" is an important agenda.

In particular, he describes how children imitate problem-solving techniques. As Vygotsky (1978) puts it, "using imitation, children are capable of doing much more in collective activity or under the guidance of adults." Children can imitate adults or more advanced peers to handle problems that would otherwise be beyond them. As Valsiner and Van der Veer (1999) point out, Vygotsky's use of the concept of imitation is more sophisticated than simple copying; it is part of a learning and developmental process. When Vygotsky argues that children "can imitate only that which is within… [their] developmental level" (1978), he is describing what he calls the zone of proximal development. Problems that are in the learners' zone of proximal development are not just those problems that they cannot yet do alone; they are problems that they have the potential to one day solve by themselves. Thus, imitation leads to internalization.

While Vygotsky used this social learning process to describe young children who were learning to do simple math problems, the scope of the process is larger. The movement from imitation to internalization is the process by which, as Vygotsky puts it, learners "grow into the intellectual life of those around them" (1978). Researchers have described how knowledge is situated in the activity, context, and culture in which it is used (Collins, Brown, & Holum, 1991; Lave & Wenger, 1991). Hutchins (1995), for example, examined the role that more experienced naval navigators play in novice crewmembers' development of essential navigational skills and knowledge. The quartermaster monitors the actions of the novice watch standers as they attempt their duties, and is ready to help or take over if they are unable to complete the task to the ship's requirements. More generally, participating in the practices of a professional community, under the supervision and guidance of mentors, gives individuals access to that profession's repertoire of ways of seeing and solving problems (Lave & Wenger, 1991). Mentoring practices in professional communities are situated in the activities that the learner is attempting to master.

Many professions have institutionalized this mentor-mentee relationship in the form of a professional practicum. Schön (1983, 1987) describes how novices participate in practices they wish to learn in "simulated, partial, or protected form" under the guidance of a senior practitioner. This way of learning is suitable for learning the mores of a professional community because professionals, more than knowing basic facts and using basic skills, have a particular way of thinking (Goodwin, 1994). They make decisions based on a set of professional values, and defend those choices with profession-specific modes of argumentation and standards of evidence--that is, with a particular professional epistemology (Schön, 1983). To learn to participate in the community of practice that Lave and Wenger describe, professionals-in-training need to learn to assume an identity and values consonant with the fundamental purposes of their profession (Sullivan, 1995).

Shaffer (2006b), building on professional repertoire, communities of practice, the role of practica in professional preparation, and Vygotsky's explanation of development, introduces epistemic frame theory. "The work of creative professionals is organized around epistemic frames," Shaffer (2006b) argues: the "skills, knowledge, identities, values and epistemology that professionals use to think in innovative ways." Yet epistemic frames are not merely collections of these unrelated elements. As Shaffer (2006b) argues, "the epistemic frame of a profession is the combination—linked and interrelated—of values, knowledge, skills, epistemology, and identity" that professionals use to see and solve problems. Professionals use their epistemic frame in the context of professional action. By simulating the world of professional practice, practica provide learners with the occasion to practice professional action, and thus develop a particular epistemic frame.

In professional practica, where learners are faced with problems that are often beyond their capabilities, mentors are there to guide them. Throughout the practicum, mentors monitor learners' performance, intervening at critical moments of confusion and struggle (Schön, 1983, 1987). While in these cases the mentors may sometimes instruct in the conventional sense (Schön, 1983, 1987), they mainly function as coaches whose conversations with the learners' highlight how to navigate the obstacles of the profession. As the novices engage in the activities of the profession, the mentors reflect, and invite the learners to reflect, on the work. In this facilitation, mentors reveal to apprentices ways to go about solving problems: they model (Collins, et al., 1991). Through these reflective conversations, mentors model a way of working that requires the complex of skills, knowledge, values, identity and ways of thinking associated with the community of practice. In short, they model the epistemic frame. In modeling the epistemic frame, mentors offer learners a professional vision that they can imitate and eventually internalize.

Shaffer (2006a) describes epistemic games as simulations of professional training, and he and others have shown that those who play them develop epistemic frames (2006a, 2006b; Svarovsky & Shaffer, 2006) which can persist months after the game is over (Bagley & Shaffer, 2009). As in practica, epistemic games feature mentors who lead learners to the right way of working. In Urban Science, for example, planning consultants guide the players through a series of activities drawn directly from ethnographic study of an undergraduate planning practicum. Urban Science provides us a case study of mentor-learner interactions that can show the formation of an epistemic frame. Conversations between players and mentors in Urban Science can show the extent to which a player not only uses elements of the epistemic frame of a practice, but the extent to which the player uses elements of the frame the way a more experienced practitioner does.

In order to accurately capture players' demonstration of epistemic frames while playing epistemic games, we have developed a method to measure how game participants link the elements of the epistemic frame during game play. Epistemic Network Analysis (ENA) is a method designed to assess learner performance based on the theory of epistemic frames. This method measures whether players develop a particular epistemic frame over the course of epistemic game play (Shaffer, et al., 2009). Epistemic games are based on a theory of learning that looks not at isolated skills and knowledge, but at the way skills and knowledge are systematically linked to each other, and linked to a set of values, epistemology and identity markers. To assess a way of thinking about a professional domain means to measure a learner's formation of connections between frame elements, because this construction of a network of skills, knowledge, values, identity, and epistemology allows the learner to see and solve problems as a professional does (Shaffer, et al., 2009). ENA measures how epistemic frame elements become linked through the co-occurrence of those elements in discourse. Mapping the connections between frame elements the way that social network analysis maps connections between people, ENA assumes that the more times frame elements occur together in discourse, the more closely they are related.

This study examines how players of Urban Science develop the epistemic frame of urban planning through one particular feature of the game, namely the mentors' modeling of the epistemic frame. Specifically, we look at players' pre and post interviews and the reflective conversations between mentors and players to see whether the players imitate and internalize the epistemic frame that the mentors model. We ask three questions. First, did the players of Urban Science develop planning epistemic frames? Second, during the game, did the players imitate the epistemic frame that the in-game mentors modeled? Finally, did the players' epistemic frames during the game persist when the mentors were not present after the game?

Methods

Study Design

In the epistemic game Urban Science, students play the role of urban planners charged with redesigning neighborhoods in their own city. Game activities were modeled on an ethnographic study of a graduate-level planning practicum, Urban and Regional Planning 912, at the University of Wisconsin-Madison. Offered as part of a summer program called College for Kids at the University of Wisconsin-Madison, fourteen middle-school age students played Urban Science four hours a day during weekdays for four weeks during the summer of 2007. Players had no prior experience with urban planning.

The four planning consultants in the game were graduate students who underwent a one-day training in the urban planning profession, the game's activities, and mentoring strategies. The mentors met before each session to plan for the day's activities, and after each session to reflect on how the session went.

Data Collection

Data were collected through individual interviews with each player before and after the game. The interviews were composed of questions about science, technology, and urban planning practices. Pre and postgame interviews from the game were recorded and transcribed. The questions asked were:

- What do think urban planning is?
- Do you think urban planning is important?
- What do you think it means to be a planner?
- How would you say urban planners get information for the plans they propose?
- Do planners ever work with other people?
- Do you think environmental issues are important to cities?

Data were also collected through recorded and transcribed interactions between the players and mentors during the game. Interactions consisted of one-on-one conversations where the mentor approached a player at work and asked a prepared set of questions, including:

- What are you working on?
- How is it going?
- If not going well: What have you tried? Why?
- If going well: Why is it going well?

Other interactions consisted of team meetings where the players stopped working, and met as a group to reflect on the work that they had been doing that day or during the previous activity. The mentor facilitated the meeting, asking questions that included:

- What were you working on today/before?
- How did it go?
- What did you try/How did you do it? Why?
- How would you do it differently next time? Why?

Some interactions were spontaneous conversations during game play. These interactions were initiated by players in need of some help, or by a mentor who observed that guidance was needed. The mentor usually asked the questions detailed above, but depending on the nature of the situation, the conversations varied.

Data analysis

Coding

Transcriptions from individual interviews were segmented into units representing one complete answer to a question, and included any follow-up questions or clarifications between the player and the interviewer. Transcriptions from in-game interactions between mentors and players were segmented into units representing one complete interaction between a player, or group of players, and mentor. A single rater coded all excerpts for elements of an urban planning epistemic frame: the interrelated set of skills, knowledge, values, identity and epistemology of the profession. The in-game interactions were coded both for the players' epistemic frames and the mentors' frames. Table 1 describes the analytic codes used in our qualitative data analysis of the in-game discourse. The analysis of the pre and post interviews used the same analytic codes.

Table 1: Analytic codes used in qualitative data analysis of in-game discourse

Code	Description	Player Example	Mentor Example
Skills	Abilities needed to become an urban planner	Crime I managed to keep low by just not adding too much high density housing.	Are there other things you can change into housing?
Knowledge	Aspects of urban planning domain knowledge	One of the stakeholders wants a lot of housing…. and I'm making sure that the business, trash, and crime don't go up too high.	Anything else in terms of zoning that you think you might have to balance?
Identity	Feelings of belonging to a urban planning community or of being a professional	Mentor: What did they say? Player 1: that our plan was sophisticated…. Mentor: did you feel sophisticated, presenting? Player 1: more… than school	But is there a way we can look at it as planners?
Values	Things that are important to urban planning practice	It was pretty easy to please my stakeholders, but this plan probably wouldn't work very well for anyone else.	They [stakeholders] are all concerned about the same thing or different things?
Epistemology	Ways of thinking about or justifying activity within the urban planning community	That's a justification we can have for crime, that when we added the needed housing for people who work in the Schenk-Atwood neighborhood and need to live there, in order to do that, crime went up by one incident per year.	Alright, so then what would be a justification for the stakeholder who wants it way lower, what would you say to that stakeholder?

For example, if during a conversation with a planning consultant a player mentions the value of serving stakeholders and the skill of zoning particular parcels to create a site plan that will satisfy those stakeholders, that player's excerpt is coded for values and skills, and those elements are considered linked at that moment. Similarly, if during a conversation a mentor asks a player to justify a particular zoning choice in light of a particular stakeholder's needs, that mentor's excerpt is coded for values and epistemology, and those elements are considered linked in that moment.

Dynamic epistemic network graphs

Epistemic adjacency matrices

For this study, the epistemic frame of urban planning is assumed to have 5 elements: skills, knowledge, identity, values, and epistemology. For any participant in Urban Science, we look at each data segment for evidence that the participant is using one or more of the elements of the urban planning epistemic frame. To construct an epistemic network from data such as this, we create an adjacency matrix for that player at that data point, recording the links between the elements of the frame for which there is evidence. For example, if in a particular segment, a player uses skills and knowledge, a link would be considered to exist between them.

By representing the epistemic frame in use during a segment as an adjacency matrix, we use the tools of network analysis to examine the cumulative impact of strips of activity on a developing epistemic frame. To construct a player's cumulative adjacency matrix, we sum the adjacency matrices of the segments of interest. We computed a series of epistemic adjacency matrices:

- one for each player's pre interview
- one for each player's post interview
- one for each player's in-game interactions, weeks 1-3
- one for each player's in-game interactions in week 3 only
- one for the players' collective in-game interactions, weeks 1-3
- one for the mentors' collective in-game interactions, weeks 1-3

Derived Network Characteristics

Weighted density provides a measure of a frame's complexity: the overall strength of association of the frame (Shaffer, et al., 2009). We compute the weighted density of an epistemic network by calculating the square root of the sum of the squares of the associations between individual elements in the network. In order to compare weighted densities when there were a variable number of strips of activity, we normalized the data by calculating an adjusted weighted density. We calculated the adjusted weighted density by dividing the weighted density by the number of its constituent strips of activity.

Relative centrality is a measure of the relative weight of an epistemic network's constituent frame elements. By extension from the weighted density of the network as a whole, we compute the weight of a frame element from the square root of the sum of squares of its associations with its neighbors. Measuring the strength of association for a given frame element emphasizes those elements with tighter linkages to individual neighbors. We compute the relative centrality of an individual frame element by dividing its weight by the frame element with the greatest weight in the network (Shaffer, et al., 2009).

Statistical tests

To compare the complexity of the players' epistemic frames between pre and post interviews, we calculated the weighted density of their frames based on their answers to pre and post interview questions. We then used a paired t-test to determine whether or not the weighted density of the players' frames significantly increased between the pre and postgame interviews.

To determine whether the players' in-game frames persisted after the game, we tested whether the adjusted weighted density of the players' 3rd week frames was correlated with the weighted density of their post interview frames. One player's third week consisted of only one interaction, so that player's data was removed.

Results

Data in this section support three claims about the experience of players in the epistemic game Urban Science. First, players developed epistemic frames by playing Urban Science. Second, the players imitated the epistemic frame modeled by the in-game mentors. Third, the players' frames, as developed in the game, persisted even when the mentors are not present, after the game.

Developing an epistemic frame

The matched pair questions players answered in post interviews contained more co-occurring frame elements than those answered in pre interviews. As a result, the weighted density of the players' post interview frames was significantly greater than that of their pre interviews (mean pre=0.1, mean post=4.4; $p<0.01$).

These changes in weighted density corresponded to a qualitative difference between players' pre and post frames. For example, one player, when asked, "What do you think it means to be a planner" in the pre interview, replied, "You sort of sketch out and you sort of visualize what will go where and how that will work out." In the post interview, the player answers the same question with considerably more detail:

> "I think it means collecting as much information as you can and it means listening to peoples' opinion and taking them into consideration. It also takes humor because you're not going to plan a place by yourself, you're going to have to collaborate with a lot of people and it takes a lot of compromising and coming up with justifications. The main goal is trying to plan and design a city and trying to improve it and making it the best you possibly can to fit the people's needs and what they want and trying to come up with a solution for all the different opinions and point of views."

Before the game, the player's answer was very vague and said generally that planners think ahead by sketching and visualizing, without any mention of the process of learning about stakeholders' needs, or working with colleagues to meet the needs of the stakeholders and the community as a whole. After the game, the player's more elaborate response refers to important elements of the epistemic frame of urban planning, like research, collaboration, compromise, and justification in the service of improving a community for its constituents.

Imitating the modeled epistemic frame

In their conversations with players, mentors modeled the planning epistemic frame. For example, in week 1, a mentor reinforced a planning value by prompting a team of players arguing about zoning decisions to remember that their job is to represent the needs of stakeholders:

> Mentor: Are you arguing your opinion or your stakeholder's opinion?
> Player 1: My stakeholders.
> Player 2: My stakeholders' opinion. I don't agree with it, but I'm arguing for them.

The mentor's question makes clear what the correct answer is. The players' responses adopt the mentor's use of the professional term "stakeholder" and the planning value of advocating for the stakeholders' opinions as opposed to one's own whims.

The mentor then follows up with another question designed to remind the planners that they are collaborators, not adversaries:

> Mentor: My other question is: whose team are you on?
> Players 1 & 2: My stakeholders…
> Player 1: Oh, our team. Our team!

By bringing to the players' attention that they are on a team together, the mentor gets Player 1 to shift her perspective from that of a simple advocate for one stakeholder group to that of a colleague whose job it is to work with a team to serve the greater public good by satisfying all of the stakeholder groups.

In week 2, player 1, now on a different team with a different mentor, and working with a different stakeholder group, now thinks of her teammates' stakeholder groups when considering zoning changes:

> Mentor 2: ….do you feel like there are some decisions you would adjust based on what you heard here and going forward to a final plan?
> Player 1: yeah cause we gotta compromise, I can't only want these people's views to push through all the problems.
> Mentor 2: So what are some of the ones you feel you might have to adjust? Taxes was one…
> Player 1: I don't know we have a lot of things in common… Robert's group doesn't really care about greenspace, but… Cheryl's group does want more greenspace and so does mine so that's one thing we have in common and also everyone here increased housing in their plan… and I think everyone wants low crime… I don't think anyone wants high crime…

The player is now prepared to compromise because she knows that planners do not only serve one group of stakeholders. She is ready to figure out how to serve the stakeholders by finding what they want "in common."

In other words, players emphasized the same frame elements that the mentors emphasized. In terms of relative centrality, the players' frame elements followed the same sequence as those of the mentors (Figure 1):

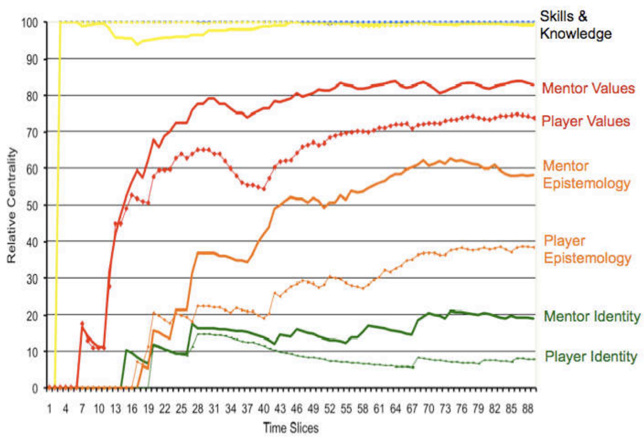

Figure 1: Collective relative centrality of players' and mentors' epistemic frames

Together, knowledge and skills were the most central for both players and mentors; as the most central frame elements, their relative centrality was always at or near 100. For both the mentors and players, the values frame element was the third most central element, the epistemology frame element was the fourth most central element, and the identity frame element was the least central element. In the conversations between mentors and players, mentors modeled a particular planning epistemic frame, and the players emulated that frame.

Internalizing the modeled epistemic frame

Comparing players' frames as adopted in the game with their frames as demonstrated in post-interviews shows a significant relationship between them. The adjusted weighted density of the players' frames in the third week of the game correlates to the weighted density of the players' post interview frames ($R = 0.6535737$, $p = .021$).

In summary, these results suggest that a) players began to develop an urban planning epistemic frame by playing Urban Science; b) during the game, players adopted the version of the urban planning frame that was modeled by in-game mentors; and, c) the planning frame that the mentors modeled and players imitated persisted after the game when the mentors were not present.

Discussion

This study examined whether a feature of one particular form of mentoring—the modeling of professional thinking that takes place in a professional practicum—was reproduced in the epistemic game Urban Science. Specifically, we looked at whether mentors' modeling of professional thinking contributed to players' development of the epistemic frame of urban planning. We addressed this issue in three parts.

First, we used ENA to examine the weighted density of players' epistemic frames in pre and post interviews. The players' post-interview frames were significantly denser. This change suggests that in answering the post-interview questions, players saw more connections between the urban planning epistemic frame elements than in the pre-interview. That is, the players of Urban Science began to develop a more complex urban planning epistemic frame. If, as Shaffer (2006b) suggests, professional thinking is characterized by "the combination—linked and interrelated—of values, knowledge, skills, epistemology, and identity," players of Urban Science appear to have developed a professional way of thinking by playing Urban Science.

Next, we used ENA to examine the relative centrality of individual frame elements of both the players' and mentors' frames, as enacted in their conversations together. In game conversations, the players emphasized the same frame elements as the mentors. As might be expected of more experienced practitioners, the mentors connected more frame elements more often, suggesting a more mature epistemic frame. But the ordinal position of the players' epistemic frame elements, and thus the shape of their epistemic frame, was the same as that of their mentors'. In other words, the players of Urban Science were able to imitate the mentors' professional way of talking about urban planning work. If, as Vygotsky (1978) argues, children "can imitate only that which is within…[their] developmental level," the players' successful emulation of the mentors' modeling suggests that the game's activities were within the players' zone of proximal development.

The zone of proximal development only describes the potential for internalization. In order to determine whether the mentors' modeled frame was adopted, not parroted, by the players, we compared the weighted density of the players' frames in the third week of the game with their post-interview frames. The weighted densities of these frames were correlated, suggesting that the imitated frame persisted after the game. This persistence is evidence that the players internalized professional thinking such that they no longer needed the mentors' scaffold. The urban planning professional thinking was in the players' zone of proximal development during the game, but in their actual development level when the game was finished. While it is unclear exactly when the transformation took place, the players of Urban Science began to achieve some autonomy in their ability to think as professionals, and that this autonomy was derived from their interactions with mentors. Vygotsky's hypothesis presupposes that learning processes, such as the imitation of modeled behavior, are converted into internal developmental processes. While this study does not claim to completely demonstrate the process by which children internalize external knowledge and abilities, the results presented here suggest that the imitation of modeled behavior is one step in the process of internalization. A second significant finding is that epistemic network analysis was shown to be a useful way to measure the development of epistemic frames, as well as the relationship between the players' and mentors' frames.

This study has limitations, which include a small sample with insufficient grounds for making causal claims, coarse-grained treatment of the epistemic frame, no treatment of mentoring strategies, and the use of a new and in-development method for understanding epistemic frame development. Still, the results here suggest several implications for people interested in mentoring, and in particular the ways players of games receive guidance from mentors. This study shows that mentors can model the sophisticated way that urban planners think, and that players of the game not only imitate the mentors, but develop the ability to think as urban planners themselves. In subsequent studies we are further examining the role of professional mentoring in epistemic games, and in particular, using epistemic network analysis to investigate the process by which players of epistemic games internalize epistemic frames.

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