Epistemic Trajectories: Mentoring in a Game Design Practicum

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Abstract: We use two constructs to examine mentoring in this practicum. *Epistemic frames*—the configurations of the skills, knowledge, identities, values, and epistemologies that professionals use to think in innovative ways—provide a model for looking at professional expertise (Shaffer, 2006). Building on epistemic frames is *epistemic network analysis* (Shaffer, et al., 2009), a method for quantifying changes in epistemic frames (Shaffer, 2010). Our claim here is that the mentor, using Schön's "Follow me!" coaching model (1987), leads the team on a path that illuminates the nature of learning to think professionally and on the function of a mentor in that process.

Introduction

There is growing concern that the 20th century mode of education, with its focus on problems with standardized answers, is leaving increasing numbers of young people unprepared for the future (Collins & Halverson, 2009). The professions—and more specifically, the processes of creating new professionals—offer an alternative model for educational activities better aligned with the abilities required to navigate a complex and changing future (Gee & Shaffer, 2010; Shaffer, 2006). Innovative professionals, who face nonstandard problems that come up in practice, often learn their particular way of solving problems in simulations of professional practice, such as apprenticeships and practica (Goodwin, 1994; Schön, 1987; Sullivan, 1995).

Recent work has described the pedagogical and developmental benefits of apprenticeship-based learning models in which young people are guided by mentors (Halpern, 2010; Rose, 2004). Other work looking at the processes by which mentors instill professional ways of thinking is also informed by an interest in how the training practices of professionals can serve as models for the development of technology-supported learning environments for K–12 students (Nash & Shaffer, 2010; Shaffer, 2006)

In this paper, we examine the learning relationship between a mentor and team of college students through an ethnographic study of a game design practicum at a European arts school. We use a novel ethnographic technique, called *Epistemic Network Analysis* (ENA), to analyze the process of mentoring in this professional setting, and argue that such an analysis is useful for further studies of professional education, as well as for studies of apprenticeship-based programs for youth.

Theory

Professional Problem-solving

Professional problem-solving is itself problematic. Problems in real-world practice are ill-formed, with potentially unlimited relevant facts and features (Schön, 1987). Thus, the problem for professionals is not only how to solve problems but how to identify them. Different professions approach ill-defined situations differently. Charles Goodwin calls the shared way that professionals see and categorize their domain "professional vision" (Goodwin, 1994). Professional vision, according to Goodwin, is employed by a community of practitioners who expect from each other a common way of organizing the world that is consistent with the values and methods of the profession. In other words, each profession is a "community of practice" (Lave & Wenger, 1991): a group of people who share similar ways of seeing and solving problems. Professional communities of practice rely on systemically organized professional values, preferences, and norms that inform their ways of seeing and solving problems (Schön, 1987). Thus, to learn to be a professional, one must be initiated into a professional community of practice.

Practica Mentoring

Many professionals join their community of practice via a practicum. In practica, novices "take on real-world projects under close supervision" (Schön, 1987, p. 37). While Schön offers some insight into the nature of the "close supervision" that mentors in practica use to help novices develop professional ways of thinking, there has been relatively little study into the ways that professional mentors do the actual work of mentoring. Schön argues that students cannot be taught, but they can be coached (Schön, 1987, p. 17). At the beginning of a practicum, learners lack both the vocabulary to talk about the work and the experience that would give that language any meaning. As they begin to do the work and talk about it with the mentor, novices imitate the mentor's talk and actions until it is internalized. Characterized by Schön as a "Follow me!" model of coaching, this way of mentoring is fundamental to the practicum experience (Schön, 1987).

Implicit in the "Follow Me!" coaching model is that the learner ultimately goes to where the mentor is: to the professional vantage where expert decisions are made. Less clear, however, is where the mentor needs to take them within the practicum. If it is the mentor's job to arrange, as Schön puts it, the "right" kinds of experiences for the learners, by what logic is an experience "right"? Schön is clear that professional expertise must be grasped as a whole in order to be grasped at all. It cannot be learned in a molecular way. If the path to professional expertise is not linear what is the path that is taken? And, what would be the logic of such a path?

Epistemic Frame Theory and Epistemic Network Analysis

In this study, we use two theoretical constructs for examining and measuring the modeling and development of professional thinking: epistemic frame theory and epistemic network analysis. The professional way of seeing the world that Schön describes as "the competence by which practitioners actually handle indeterminate zones of practice" (1987, p. 13) has been further explicated by Goodwin (1994), who describes the ways practitioners highlight and elide things that are important or not according to their professional perspective, and Sullivan (1995), who explains how professionals employ an ensemble that includes intellectual, practical, and ethical components. Shaffer extends these insights by pointing out that it is "the combination—linked and interrelated—of values, knowledge, skills, epistemology, and identity" that characterizes the professional ensemble. This combination, what he calls the *epistemic frame,* emphasize the ways that ways seeing and solving problems are linked in practice (Shaffer, 2010). For example, a reporter may write a certain way because she views her job as serving the societal function of being a community watchdog. In this epistemic frame, a particular journalistic skill is informed by a specific journalistic value and a sense of professional identity.

ENA is a technique for quantifying and analyzing an epistemic frame (Shaffer, et al., 2009). It adapts a social network analysis framework—for mapping social elements—to instead map the constituent elements of complex thinking. In social network analysis, the objects of interest are not the individual actors but the structure of the relationships among those actors. Similarly, epistemic frame theory suggests that complex thinking is not characterized merely by a collection of values, knowledge, skills, epistemology, and identity, but rather by a particular structure of relationships or connections between these components of expert practice. Thus, analyzing thinking in terms of simple counts of frame elements in an (aspiring) professional's frame is not sufficient to account for the development of expertise. Instead, ENA uses co-occurrence of frame elements in discourse to model the pattern (or patterns) of association characteristic of a particular professional community. By quantifying the relationships between epistemic frame elements, ENA describes and quantifies the structure of an epistemic frame. Where one frame may have one set of important relationships between its constituent elements, another frame may emphasize different relationships. ENA provides a method for examining when and how often frame elements are linked, and can show trends in how epistemic frames change over time, between individuals, or across different interactional contexts (Nash & Shaffer, 2010). ENA is thus a potentially useful tool for comparing the epistemic frames of a team of learners and a mentor in a practicum.

Many of the studies that examine the learning that takes place in a practica rely on surveys (Ryan, Toohey, & Hughes, 1996), which do not measure learning in situ and rely on self-report data, or are qualitative ethnographies (see, for example, Hutchins, 1995). While both of these methods shed light on the processes of learning and of mentoring in a practicum, ENA is a potentially useful addition to the scholarly toolkit because it can quantify thinking in the context of action. In the case of a practicum, the conversations between mentor and learner provide the occasion for the mentor to model professional thinking and for the learner to imitate that modeling (Schön, 1987).Using ENA to examine the reflective conversations in the practicum, we can examine whether (and, more important, how) the team of learners "follows" the mentor, as suggested by Schön's model.

We operationalize such a question by comparing the "distance" between a mentor's frame and the learners' collective frame when they have meetings together across the time of the practicum. By distance, we mean the projection of the structure of the epistemic frame, as quantified by ENA, in to a high dimensional space. Using multi-dimensional scaling, we can visualize epistemic trajectories: models that show the distances between team and mentor's frames throughout the practicum change over time. Finally, constructs borrowed from social network analysis can help us interpret these trajectories. For example, the relative centrality of a frame element quantifies the extent to which it is connected to other elements in the professional discourse, and therefore can help us interpret the mathematical concept of "distance" by suggesting in what ways two different frames are similar or different.

This study: Game design practicum

The starting point for this study is the idea that in a practicum a mentor leads learners through the authentic work of a professional practice and that though his coaching the learners develop a particular epistemic frame. As in all practica, the students in a game design practicum do the work that professional game designers do. They seek to create games that feature *meaningful play*, which game design experts describe as occurring "when the relationships between actions and outcomes in a game are both discernable and integrated into the larger context of the game" (Salen & Zimmerman, 2004, p. 34). In other words, a critical job for game designers is to make a game in which players can perceive the immediate outcome of the actions they take—the relationship between action and outcome in games is often called *gameplay (*or *game mechanic)*—and that those outcomes are consistent with the game as a whole. The game as a whole, also known as the game concept, can be simple (e.g. Angry Birds) or complex (e.g. World of Warcraft), and encompasses the vision of the overall player experience of the game. It often includes narrative elements, and in the case of educational or "serious" games, learning goals (Abt, 1970; Gee, 2003; Squire & Jenkins, 2004). Both gameplay and game concept simulate some phenomena that is usually, but not exclusively, real-world phenomena (Salen & Zimmerman, 2004, p. 457). Thus, one important activity in game design is researching the phenomena to be simulated, which are referred to as the *content domain*. Learning to link these three elements of game design—*gameplay*, *game concept*, and *concept domain*—is a fundamental task of building a game.

This study looks at the role of mentoring on the learning trajectory of the team of students as they develop these and other elements of game design's epistemic frame. Although the study is, of course, situated in an examination of one particular practicum, our hope is to show how this analytical method can reveal learning processes in practicum and similar settings. We ask three questions:

1. Does the team "follow" the mentor in the sense that the team and mentor's frames during meetings become more similar over time?
2. Where does the team follow the mentor? Specifically, do the team and mentor's frames converge in linear trajectories?
3. Whether the convergence is linear or not, why does it have the observed form?

To answer these questions, we first conduct a qualitative (ethnographic) analysis of the practicum. Then, we triangulate this analysis in quantitative terms using ENA.

Methods

Setting and participants

The game design practicum took place in an undergraduate level arts school. The semester-long practicum wass organized around the production of a single game. Student teams were assigned a client, who provided the team with their assignment. In this case, the team learned that they needed to create a game to encourage consumers to choose sustainable fish to eat. The team was comprised of seven students. The mentor assigned to work with the team is a professional designer and developer of educational software.

Data Collection

We observed every team meeting until the midterm review. Meeting data were collected in digital audio recordings. Recordings were transcribed to provide a detailed record of interactions. We interviewed the team's mentor twice during the two months, asking general questions about game design, as well as specific questions about the progress of the team and his ideas about his role as a mentor. We conducted the same type of interview with two other mentors assigned to different teams.

Data Analysis: Coding Scheme

From interviews conducted with three mentors at the school, we used a grounded theory approach (Strauss & Corbin, 1998) to generate a set of 32 qualitative codes representing the epistemic frame of game design. Three frame elements were of particular interest in this study: the knowledge of game mechanics, the knowledge of the content domain, and the skill of developing a game concept.

Data Analysis: Segmentation and coding

This study is based on three team meetings at which the mentor was present. We segmented the three meetings into interactive units ("stanzas") which were defined as sequences of utterances with a consistent topical focus. For example, if the team started discussing their strategy for an upcoming meeting with a client and then switched to discussing the profile of their target users, the switch in discourse topic would indicate two separate interactive units. There were 14 stanzas in the first meeting, 17 in the second, and 24 in the third. For the three team meetings, we coded each stanza for the contributions of both the mentor and the team for articulations of the elements of the game design frame (as generated from the interviews with the three mentors). If discourse in the stanza was determined to meet the criteria of a code's definition, that stanza was coded with a '1' for that code. If none of the discourse in that stanza met the criteria of the code's definition, that stanza was coded for a '0' for that code. The team's contributions were coded collectively: if no team member discussed a given frame element, that stanza would be coded with a 0 for that element, but if at least one team member talked about a given frame element, that stanza would be coded with a 1 for that element.

Data Analysis: Measuring frames

Adjacency Matrices

We created an adjacency matrix for each coded data segment (each stanza of each meeting). Adjacency matrices record the links between individual frame elements. When a pair of elements co-occur within a stanza, they are considered conceptually linked (Shaffer, 2010). We summed each meeting's constituent stanzas' adjacency matrices to construct final adjacency matrices for the team and mentor for each meeting.

Relative Centrality

For the mentor and the team in each meeting, we calculated the relative centrality of each of the frame elements that constitute their epistemic frames. Relative centrality is a measure of how often each element is connected to all of the other elements in discourse; in other words, it is a measure of the relative weight of an epistemic frame's constituent elements (Shaffer, et al., 2009). To compute the *centrality* of a frame element, the square root of the sum of squares of its associations with its neighbors is calculated. To compute the *relative centrality* of an individual frame element, its weight is divided by the frame element with the greatest weight in the network (Shaffer, et al., 2009).

Data Analysis: Comparing frames

Frame Similarity Index (FSI)

The Frame Similarity Index provides a testable measurement of the similarity between two epistemic frames. The Euclidean distance between two frames is calculated by finding the root mean square of the differences of the relative centrality of each frame element between the two frames. Thus, identical frames would have an FSI score of zero. The maximum theoretical distance between two frames is the Euclidean distance between a frame where every element has a relative centrality of 100 (all possible connections) and a frame where every frame element has a relative centrality of 0 (no connections). The maximum theoretical distance between two frames with 32 constituent frame elements would be 565.68. Dividing the distance between the two frames by the maximum possible distance between those two frames provides the distance expressed as a percentage of the maximum possible distance.

To estimate confidence intervals for the difference between two frames, a jackknifing method can be used, in which the relative centralities are systematically recomputed leaving out one stanza at a time. The standard deviation and confidence intervals of the FSI statistic are then estimated from the variability within the calculated subsamples.

Data Analysis: Epistemic frame trajectories

To see all of the team and mentor's meeting frames in relation to each other, and to more accurately compare those frames, we require a more sophisticated model: epistemic frame trajectories. First, the distances between all points of interest are calculated using FSI. In the case of this study, those points of interest are the mentor and team's frames in each of the three meetings. These distances are organized in a symmetric distance matrix, made up of 6 distance vectors. A classical multidimensional scaling (MDS) algorithm is applied to the distance matrix in order to identify the dimensions that capture the most variance in the data. Because MDS does not preserve directionality, specific dimensions in the low dimensional projection are not interpretable (Bartholomew, Steele, Moustaki, & Galbraith, 2008). However, relative position in space is still meaningful in that points closer together in the high-dimensional space have more similar patterns of co-occurrence than points farther apart.

Using these tools, we operationalize our research questions in the following ways:

Research Question 1

Does the team follow the mentor? In other words, do the team and mentor's frames during meetings become more similar over time? To answer this question, we used FSI to measure the distance between the team and mentor's frames in each of the three meetings. We looked to see whether the distance between the team's frame and the mentor's frame was reduced with each successive meeting.

Research Question 2

Where does the team follow the mentor? In other words, do the team and mentor's frames converge in linear trajectories? To answer this question, we constructed epistemic frame trajectories to show the distances between the team and mentor's frames across the meetings in a two dimensional projection of a multidimensional space. We used multi-dimensional scaling (specifically principal coordinates analysis) to create two dimensional trajectories from the six dimensional space of the team and mentor's meeting frames. We used the second and third of the resulting six dimensions to display the two dimensional trajectories. Although the first dimension captured the most variance, and thus could be argued to be the most important, it appeared to be highly correlated with time. Since we already knew that the meetings were separated by time, we considered the second and third dimensions more revealing.

Research Question 3
Why do the trajectories have the observed form? To explain the logic behind the trajectories, we examined the change in relative centralities of the frame elements across the three meetings for both the team and mentor. Since the positions in the epistemic trajectories are determined by FSI scores, which in turn are calculated by the similarity of the relative centrality of the frame's constituent elements, changes in relative centrality would influence the position of the team and mentor's epistemic frames with each meeting.

Results
We describe our observations of the game design practicum in four parts below. The first part is a qualitative look at the three meetings, and the final three parts quantify what was observed in that qualitative investigation.

Qualitative results
The team had met before their first meeting with the mentor and had brought a list of brainstormed game concepts. The mentor ran the first meeting, and was critical of the team's work. He felt that not enough work had been done, that the team was not adequately organized, and that they were prioritizing the wrong things. When one student observed that they had "mostly just talked a lot," the mentor agreed, telling them to "quit the endless brainstorm and start working." None of the team's game concepts were grounded in either a vision of gameplay or rigorous research; as one student admitted, "There isn't any gameplay yet." In response, the mentor reinforced the link between gameplay and game concept, telling the team that "the challenge of your game has to be in line with your educational challenge."

The mentor was similarly explicit about the link between game concept and the content domain. Noting that the team's research into the content domain was "okay", the mentor urged the team to "do the next step of research… if you want to do the fish tycoon concept that means you have to do a lot of extra research on fish management and business." The main problem with the team's work in this stage was that their game concepts were not connected to game play or a content domain. The mentor sent the team away with instructions "to fill it in. A lot of concepts seem nice, but then you [need to] fill it in."

The second meeting was run by the team. They had, as the mentor had instructed, done "the next step of research." They spent most of the second meeting reporting their research on the content domain. The mentor prompted the team to be explicit about the utility of their new information, at one point asking, "So, what is the main question you need to know for your game with respect to the storing of the fish?" Much of the activity in the meeting was precisely this kind of decision making. For example, a student remarked how "it's very important to be more specific about what fish we're going to use." When the mentor asked whether the team was deciding to abandon fish farms as part of their game concept to focus more specifically on fish marts, one student responded, "we have to map the game completely." Mapping the game completely required the team to describe the concept and game play in terms of the content that they had researched. Although the second meeting focused on content, the mentor still reinforced the link between game mechanic and game concept; as the team was figuring out what to do next, the mentor reinforced again the three elements together, explaining, "it's important to first get your idea of gameplay clear…. to rev up the research…. [and to] elaborate on the design idea" Although all three are important, he suggested that the team now turn their focus on game play.

The third meeting was also run by the team. They were planning on conducting play-tests of some of their game prototypes, in order to get feedback on the game mechanics, and also preparing for a mid-term presentation, at which they needed to present their game concept and reports of the research they had done to support their design. The team discussed a number of prototypes for mini-games within their game concept. The mentor continued to give advice about the three key frame elements. In a discussion about one of the mini-games the team was creating for their game, the mentor talked about the "story" of the game:

The story has to be matching the reality. If you say there's always bad-catch, you can only say that if that's the reality. Or you could say, this is just ordinary fishing…. Then later in the story maybe you say something about environmental, dolphin-friendly tuna. Or you play this game again and the score is really [about how you] find and get no dolphins or throw the dolphins out again.

The game story is a way of talking about the game concept: the sequence of challenges the player must face in order to complete the game and, since this is a "serious game," to learn the intended lesson. Both the sequence and the individual challenges must make sense internally (in terms of the game mechanic) and externally (in terms of the content domain). One student demonstrated these connections in their discourse by using content domain language to describe how the gameplay must be persistent in their concept:

One game is like fishing in the Baltic Sea and avoiding environmentalists. The other is scaring off locals with your bulldozer. The other one we haven't defined yet….in the end, all those things have to be present again.

Result 1: Following the mentor?

The frame similarity index (FSI) was calculated to compare the team's epistemic frame and the mentor's epistemic frame in each of the three meetings. In the first meeting the distance between the team and mentor's frame is .208 (95% CI [.212, .214]), in the second meeting the distance is .166 (95% CI [.162, .169]), and in the third meeting is .128 (95% CI [.127, .129]). With each successive meeting, the team's game design frame was closer to the mentor's in the same meeting. This result suggests that the team increasingly mirrored the mentor's game design discourse in the meetings.

Result 2: Following the mentor where?

To examine the team and mentor's paths, we created epistemic trajectories of the mentor and team's frames across the three meetings. The trajectories show the convergence reported above, with the team and mentor frames becoming successively similar with each of the three meetings (Figure 1).

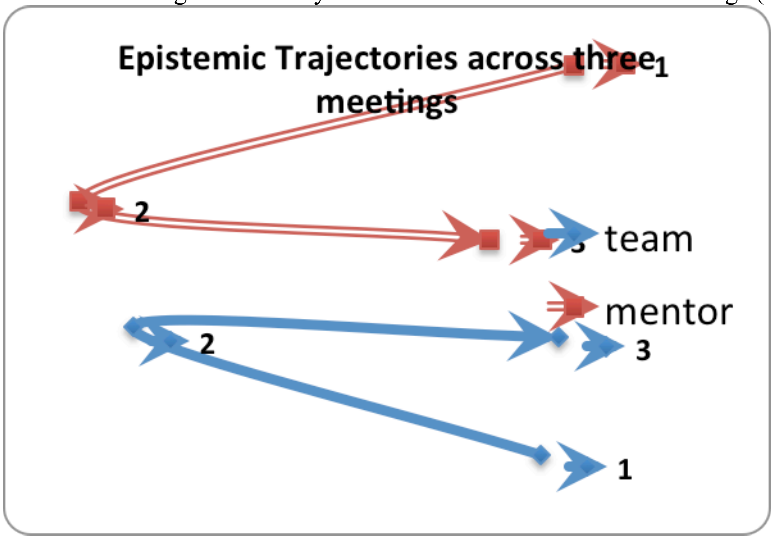

Figure 1: Team and Mentor Epistemic Frame Trajectories

Although the distance between the team and mentor's frame was reduced with each meeting, both the mentor and team's frames in the second meeting were much further from the frames in either the first or third meetings. In other words, the team's third meeting and first meeting frames were more similar than their frame in the second, and the same is true for the mentor. These trajectories suggest that the team's epistemic frame development did not proceed uniformly from the first to the final meeting.

Result 3: Why that path?

To see what might have caused the nonlinear trajectories, we looked at the change in the relative centralities of three key frame elements across the three meetings (Figure 2). This figure shows the relative centrality of the skill of *concept development*, the knowledge of *game mechanic*, and the knowledge of the *content domain* in the mentor and team's frame in each of the three meetings.

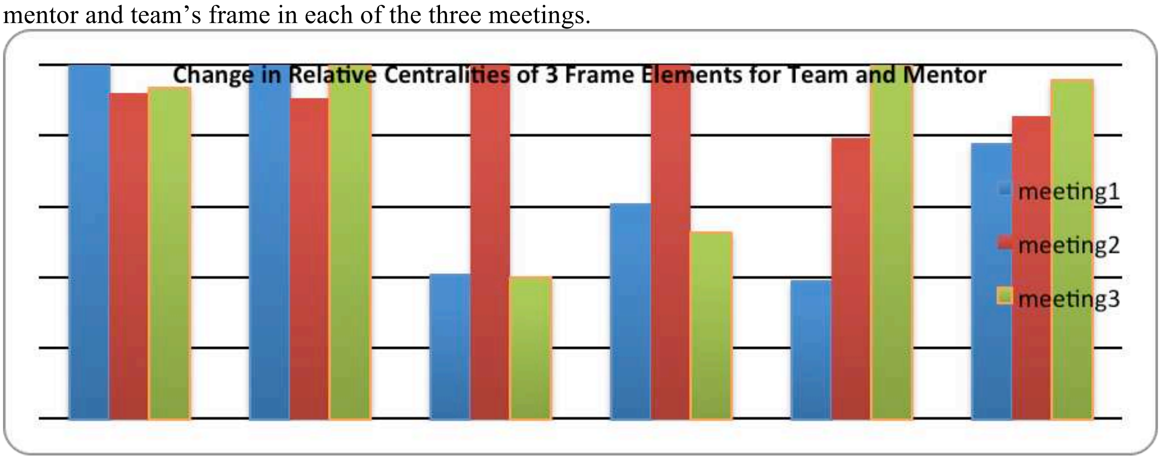

Figure 2: The change in importance of frame elements.

The development of a concept is important for both the team and mentor in all three meetings. In the second meeting, and only the second meeting, content research becomes the most central concern. Finally, we see that the game mechanic becomes increasingly important across the three meetings. The spike in the relative centrality of K/Content Domain would appear to explain the large distance between the frames in the second meeting and the other meetings.

Discussion

The results presented here describe how a team of novices in a practicum come to think like professionals under the guidance of a mentor. By the time the practicum was half over, which was the end point of this study, the team needed to have a game concept and game mechanic that were tightly bound together and that simulated a well-researched content domain. This study is about the path and mechanism by which the team arrived there.

First, the team imitated the discourse of the mentor. The team's epistemic frame grew more similar to the mentor's frame with each meeting. A feature of the “Follow Me!” coaching style is the mentor’s demand that the learners imitate (Schön, 1987). It is possible that the increasing similarity of discourse in the later meetings is due to differences in the degree of freedom in the conversational topics: perhaps earlier in the practicum the conversations were simply more “open-ended.” We argue, however, that the convergence of professional discourse is by design, not happenstance. The conversations the team had in their meetings were informed by the particular intentions and direction of their mentor as well as the general construction of the practicum. Regardless of whether any particular topic of conversation was due to one or the other, the conceptual development of the game designer frame requires this convergence. The “Follow me!” coaching model serves to guide learners who are doing work without necessarily knowing how to do it or why they are doing it.

The epistemic frame trajectories show the path down which the mentor led the team by offering an additional perspective on how the team and mentor’s frame’s converged. Mentors and students did not take a “direct route” from where they started to where they each ended. Instead, their second meeting, distant from the first and third meetings, indicated a developmental “detour.” The change in the importance of three key frame elements— similar for the mentor and team across the three meetings—helps explain indirect path. The development of a concept was important in all three meetings. In the second meeting, the content domain became the most central concern. The game mechanic became increasingly important across the three meetings.
Although the game ultimately must have a mutually reinforcing concept and mechanic, the mentor first led the team to other connections: to the connections between the content domain that the game is simulating and both the game concept and mechanic. That is, the development of a concept and game mechanic rely on the development of an understanding of the content domain. The students progressed from where they “mostly just talked” without “any gameplay yet” to where they used content domain language to link their game mechanics to their game concept. In other words, the mentor concentrated on one part of the frame in order to scaffold another part of it, which suggests that the detour in the epistemic trajectories was not a detour at all. Rather, the shortest distance from novice to professional thinking may not be to simply model best expert practice.

That the team has this indirect trajectory is perhaps unremarkable. After all, sometimes learners take steps backward on their trajectory forward. That both the team and the mentor share this type of trajectory, on the other hand, implies a learning experience quite different from the way traditional curricula, instruction, and assessment are organized. Most school subjects, for example, are organized to be taught in a strictly atomized and sequential manner. If learning to think like a professional requires rather than just accommodates indirect learning trajectories, as these results suggest, then the type of coaching by which mentors scaffold different connections within an epistemic frame is a type of learning relationship that deserves more attention.

Another valuable finding of this study is that ENA was shown to be a useful way to quantify the development of epistemic frames, as well as the relationship between the students’ and mentor’s frames. Other methods of discourse analysis may offer similar or additional results to those found in this study. However, the promise of ENA is that it is driven by frequencies of the co-occurrence of qualitative codes, and thus captures how practitioners connect the aspects of professional vision. In particular, projecting the distances between interactive units—whether they be meetings, activities in within meetings, turns of discourse within activities, or who the unit is associated with—by creating epistemic trajectories is a promising way to explore the nature of developing epistemic frames and complex ways of thinking in general.

The results presented here have several limitations. The ethnographic nature of this study means that any conclusions are limited to what one particular group did in the context of one particular practicum. Further, this study focuses on a limited amount of data. Team activity without the mentor may have added information about aspects of the epistemic frame the team internalized. Similarly, examining epistemic trajectories within meetings would allow us to map how frames developed in relation to the activity and discourse in the meetings. In addition, when looking at the relationships between the mentor and student frames, this study treated the students as a team, and so does not show individual development. The “Follow me!” coaching strategy might work differently for different students, differently during different activities or at different stages of the practicum. Finally, ENA is a new method for understanding the development of an epistemic frame. As such, we expect it to develop in ways that allow us to better test significant events in frame development. Despite these limitations, the results here suggest that focusing on how mentors coach learners to develop epistemic frames should be useful for further studies of professional education or of apprenticeship-based programs for youth, and that epistemic network analysis is a useful tool for uncovering these learning processes.

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