Mentor modeling: the internalization of modeled professional thinking in an epistemic game

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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 examined the interactions between players and mentors in one epistemic game, Urban Science. Using a new method called epistemic network analysis, we explored 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.

Keywords

educational games, mentoring, assessment.

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 – was 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. Epistemic games are computer-based role-playing games that simulate professional training. Epistemic games recreate in game form professional practica such as design studios, capstone courses, and other occasions where professionals-in-training work in a supervised setting to prepare for entry into the workforce. Urban Science, for example, is modeled on a practicum course for graduate urban planning students (Shaffer 2006b). In the planning practicum, students are hired by organizations to complete a planning project: with the help of a mentor, they visit the site in question, meet with stakeholders, use geographic information system (GIS) models to weigh tradeoffs, create preference surveys and final plans, and present their findings (Shaffer 2006b). In Urban Science, players as young as 12 years old do these same things: they log into an online portal where they receive instructions from their non-player-character supervisors, go on virtual site visits, use a GIS model, write preference surveys and receive feedback, and present their final plans, all with the help of mentors who can look over their shoulders as they work.

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 profes-
sion: what Shaffer (2006a) calls the *epistemic frame*.
This paper looks at whether this same form of mentor-
ting takes place in one epistemic game, and if so,
whether it has the same effect as mentoring in the pro-
fessional 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 and
to this epistemic game, the type of mentoring and learn-
ing that happens in epistemic games could be useful
models for designing new types of educational settings,
in schools or elsewhere.

**Theory**

There is extensive research on the role that mentors can
play in promoting positive behaviour and habits in
youth (DuBois *et al.* 2002; DuBois & Silverthorn
2005). Vygotsky’s (1978) work on cognitive develop-
ment describes the role of mediating agents in the
child’s social learning environment: namely that the
development of the child’s higher cognitive processes
depends on their presence. While Vygotsky himself
‘emphasized symbolic tools-mediators appropriated by
children in the context of particular sociocultural activi-
ties, the most important of which he considered formal
education’ (Kozulin 2003, p. 17), 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 cogni-
tive 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 par-
ticular 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 chil-
dren become internalized’ (Vygotsky 1978, p. 91) is an
important agenda.

In particular, Vygotsky (1978, p. 88) describes how
children imitate problem-solving techniques; as he 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, p. 88), he is describ-
ing 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, imita-
tion 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, p.
88). Researchers have described how knowledge is situ-
atated in the activity, context, and culture in which it is
used (Collins *et al.* 1991; Lave & Wenger 1991). Hutch-
ins (1995), for example, examined the role that more
experienced naval navigators play in novice crewmem-
ers’ 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 gen-
erally, 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 socio-cultural explanation of cognitive development, introduces epistemic frame theory. ‘The work of creative professionals is organized around epistemic frames,’ Shaffer (2006b, p. 12) argues: the ‘skills, knowledge, identities, values and epistemology that professionals use to think in innovative ways’. Professional thinking requires the mastery of knowledge and skills, to be sure, but in the context of actual work, professionals rely on professional values to direct their skills and knowledge. Similarly, professionals assume certain identity markers that help them identify themselves as members of the group. And finally, they agree on accepted ways of justifying their decisions, an epistemology. Yet epistemic frames are not merely collections of these unrelated elements. As Shaffer (2006b, p. 160) 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. Practica, in simulating the world of professional practice, provide learners with the occasion to practice professional action – in essence, to begin to develop the epistemic frame of that profession.

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). As Schön describes, while in these cases, the mentors may sometimes instruct in the conventional sense, 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 of how to accomplish professional work, mentors reveal to apprentices ways to go about solving problems. In helping the apprentice, they show the way it is done: 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.

Assessing mentor modeling in epistemic games

There is a literature on educational games (Gee 2003; Squire & Jenkins 2004), and in particular literature that describes the theory behind epistemic games or other games that are based on rules and roles (Salen & Zimmerman 2004; Shaffer 2006a, 2006b, 2010). Shaffer (2006a) describes epistemic games as simulations of professional training in which players play the role of novice professionals. Shaffer and others (Shaffer 2006a, b; Svarovsky & Shaffer 2006) have shown that those who play epistemic games develop epistemic frames; in addition, these developed frames 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, both mentors and players, link the elements of the epistemic frame during gameplay (Shaffer et al. 2009). Called Epistemic Network Analysis (ENA), this method allows us to look at when and how often these frame elements are linked, and the relationship between trends in the players’ demonstration of the epistemic frame and different features of the game. 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.

Research questions
This study asks 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? And finally, did the epistemic frames that players demonstrated during the game with the mentors persist when the mentors were not present after the game?

Methods
Study design
Background
In the epistemic game Urban Science, students play the role of urban planners charged with redesigning neighbourhoods 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. The planning practicum’s series of activities included:

- background research, where novice planners read about the history of the planning site, including past planning decisions that have impacted it.
- a site visit, where novice planners learned about the features of the planning challenge from first-hand observations and meetings with stakeholders.
- the creation of preference surveys, where novice planners prepared alternative plans using GIS software to elicit feedback from stakeholders about features of the neighbourhood they wanted preserved.
- staff meetings, where teams of novice planners discussed information gathered and proposed planning solutions.
- drafting of a final plan, where teams decided on and constructed a proposed plan using GIS software.
- proposal preparation, where teams developed a presentation that explained and justified their proposed plan.
- final proposal, where teams presented their proposals to relevant stakeholders.

Gameplay in this version of Urban Science adapted these activities to be played by middle-school age students.

Participants
Offered as part of a summer programme called College for Kids at the University of Wisconsin, Madison, 14 middle-school age students played Urban Science 4 h a day during weekdays for 4 weeks during the summer of 2007. Players had no prior experience with urban planning.

The four planning consultants in the game, who guided the players in team meetings and as they worked, were played by graduate students who underwent a 1-day training that covered the urban planning profession, the game’s activities, and preferred mentoring strategies. In addition, the mentors met as a group before each session to plan for the day’s activities, and after each session to reflect on how the session went.

Game structure
In the game, players redesigned three neighbourhood sites in Madison: State Street, Schenk-Atwood, and the Northside. Each of the first 3 weeks focused on the redesign of a single neighbourhood site; in the fourth week, the players created a comprehensive plan that incorporated redesigns of all three sites. This study focuses on the first 3 weeks of the game.

The sequence of the activities was the same in each of the first 3 weeks. The game began with the players arriving at a computer lab at the University of Wisconsin, Madison; this lab served as the office of the fictional urban planning firm called Urban Design Associates.
The players signed into the game website, an intranet portal, where they found many of the tools that they would use to play the game (Fig 1).

Once signed in, the players checked their inboxes and received emails from non-player characters (NPCs), including the head planner and community facilitator, who explained the planning process and tools used in the game, provided background materials, and collected and assessed work products. Players were directed to read the City Council’s Request for Proposals (RFP), conduct background research on their site assignment, and write a background report summarizing the site’s important characteristics and especially any historically significant planning decisions. For example, the RFP for State Street, a popular pedestrian thoroughfare in Madison, Wisconsin, states that:

... a new plan for State Street will provide a unique opportunity for Madison to develop a long-term vision to address unmet wishes of stakeholders within the city and continue Madison’s tradition of balance between urban and ecological needs. The anticipated planning shall focus on maximizing civic utility by addressing economic development and housing concerns for the area. Proposals must incorporate approaches for analyzing impact on trash, sales revenue, jobs, greenspace, parking, housing, crime, and cultural index to be considered.

For each neighbourhood site, players acted as planning advocates for one of four stakeholder groups. For example, the stakeholder groups concerned with the development of State Street were:

- Business Council
- People for Greenspace
- Equal Opportunities for All
- Cultural Preservation Organization

Equipped with digital cameras, players traveled to the site to conduct a site visit. On the site visit, players
took photographs features of the site that they thought should be preserved or changed. Upon returning to their office, they filed a neighbourhood assessment comprised of their photographs, descriptions of the features they photographed, and justifications for why they thought the features should be changed or preserved.

Next, working in teams, players conducted a virtual site visit, in which they interviewed NPCs representing stakeholders in the community to find out what types of issues they cared about. For example, one stakeholder from the State Street site, Ed, says:

Hi! My name is Ed and I helped form Equal Opportunities for All because there are a lot of good people in this world that can’t normally afford high quality housing. Our organization works with people like you to find places to develop housing properties to help first-time renters and homeowners establish themselves, particularly for individuals that have respectable jobs but can’t normally afford a home. We’ve noticed that State Street currently only has housing available to groups that can afford to pay incredibly high rents, which we think is inappropriate. We recommend finding a way to include more housing on State Street so that more hard-working, blue-collar individuals can afford to live in a great place like State Street.

The players recorded the stakeholders’ opinions in their planning notebooks, and then began to translate their findings into proposed land use changes. To propose land use changes, they used iPlan, an interactive GIS model of the planning site that let them assess the ramifications of those changes. In iPlan, players could change zoning designations for the parcels, units of land held by a single owner. Zoning codes were represented on the map in a unique colour (Fig 2):

The iPlan model also included graphs representing social and economic indicators important to each neighbourhood site. For example, the issues that were impacted by zoning changes to the State Street site were:

- Crime
- Cultural index
- Greenspace
- Housing
- Jobs
- Parking
- Trash
- Total sales

As players made changes in the zoning of parcels, the graphs dynamically updated, showing the projected impact of the zoning changes on the social and economic conditions of the neighbourhood. For example, if players chose to rezone a large arts complex as a surface lot to increase parking, not only would the cultural index decrease, but jobs and total sales would also suffer. Any single change to the physical representation of a site resulted in changes to its eight indicator values.

Using iPlan, in other words, players saw a physical representation of the site, the land use allocations for the street, and the consequences of their zoning changes (Fig 3).

Using iPlan, players worked in their stakeholder teams to construct preference surveys. As in the planning practicum, preference surveys in Urban Science were a set of possible planning alternatives designed to elicit information about the desires and hopes that stakeholders had for their neighbourhood. Specifically, players in Urban Science developed and used preference surveys to try to determine the minimum or ‘threshold’ values that would lead stakeholders to support (or reject) a proposal. For example, players might have used a preference survey to determine how many additional housing units were needed in a plan to gain the support of the Equal Opportunities for All stakeholder group – or how many additional square feet of parks were needed for the support of the People for Greenspace.

Once completed, players submitted their preference surveys to their stakeholder group. The virtual stakeholders responded to the preference surveys through short dialogue based on the specific indicator levels, delivered in the form of a printed report from a focus group. For example, one player working with the Equal Opportunities for All received the following feedback from the stakeholder, Ed:

I’ve looked at your plan and there’s really no way that it’s going to work for us. There just isn’t enough housing on the street! With so few places to live, landlords will be able to raise rents as much as they want, and there will be even less affordable housing. I’m sorry, but this is unacceptable.

Next, players held a staff meeting with their planning teams to summarize the feedback they received. Each planning team presented their findings to the group as a whole, and new planning teams (with one player from each stakeholder planning team) were formed to draft a final plan.
Each team used iPlan to create a final plan that could incorporate the needs of all of the stakeholder groups. When plans were complete, each team prepared a presentation of their findings and recommendations, which was delivered to a local planner acting as a representative of the city council.

**Data collection**

*Individual pre/post interviews*

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 post-game interviews from the game were recorded and transcribed.

The questions asked were:

- What do you 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?

![Zoning code reference: State Street](image)
In-game interactions
Data were also collected through recorded and transcribed interactions between the players and mentors during the game. There were three types of interactions between players and mentors.

The first type 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?
The second type consisted of team meetings where player teams met to reflect on the work that they had been doing. 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?

The third type of interaction consisted of spontaneous conversations between players and mentors during gameplay. These interactions were initiated either by a player or group of players in need of some help, or by a mentor who saw that some guidance was needed. The mentor usually asked the same questions as detailed in the first type of interaction, but depending on the nature of the situation, the conversations varied.

As detailed in Game Structure, once the players began working on their final plans, the teams shifted so that every final plan team was comprised of players who had conducted a preference survey with different stakeholder groups. With each new week, and each new neighbourhood site, the player personnel in the stakeholder teams varied. The mentors, assigned to different teams throughout the game, worked with all of the players, but the amount any one mentor worked with any one player varied week to week.

Data analysis

ENA is a method designed to assess learner performance based on the theory of epistemic frames. This method measures whether epistemic gamers develop a particular epistemic frame over the course of gameplay (Shaffer et al. 2009). Epistemic games are based on a theory of learning that looks 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 it is this construction of a network of skills, knowledge, values, identity, and epistemology that allows the learner to see and solve problems as a professional does (Shaffer 2006b; Shaffer et al. 2009). ENA is an appropriate assessment because it measures the extent to which epistemic frame elements become linked.

ENA measures the links between frame elements through the co-occurrence of those elements in discourse. Social network analysis uses analytical tools for representing networks of relationships between people, which are ‘similar to . . . the complex and dynamic relationships of the kind that characterize epistemic frames’ (Shaffer et al. 2009). Social network analysis might use data on the number of times people interact in a social situation to create maps to determine the connections between those people. ENA uses maps of the connections between frame elements the way that social network analysis might map connections between people. ENA makes the assumption that the more times frame elements occur together in discourse, the more closely they are related.

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’ and mentors’ epistemic 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.

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

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
<th>Player example</th>
<th>Mentor example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skills</td>
<td>abilities needed to become an urban planner</td>
<td>. . . crime I managed to keep low by just not adding too much high density housing.</td>
<td>Are there other things you can change into housing rather than changing existing housing? And would that make an impact?</td>
</tr>
<tr>
<td>Knowledge</td>
<td>aspects of urban planning domain knowledge</td>
<td>. . . one of the stakeholders wants a lot of housing. . . and I’m also making sure that the business, trash, and crime don’t go up too high.</td>
<td>Anything else in terms of zoning that you think you might have to balance?</td>
</tr>
<tr>
<td>Identity</td>
<td>Feelings of belonging to a urban planning community or of being a professional</td>
<td>Mentor: What did they say? Player 1: That our plan was sophisticated. . .</td>
<td>But is there a way we can sort of look it as planners?</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mentor: Did you feel sophisticated, presenting? Player 1: Kind of Player 2: Yeah Player 1: More sophisticated than like, school</td>
<td></td>
</tr>
<tr>
<td>Values</td>
<td>things that are important to urban planning practice</td>
<td>It was pretty easy to please my stakeholders, but this plan probably wouldn’t work very well for anyone else.</td>
<td>They [stakeholders] are all concerned about the same thing or different things?</td>
</tr>
<tr>
<td>Epistemology</td>
<td>ways of thinking about or justifying activity within the urban planning community</td>
<td>. . . what’s a justification we can have for crime, that when we added the needed housing for people who work in the Schenk-Atwood neighbourhood, and need to live there, in order to do that, crime went up by one incident per year.</td>
<td>Alright, so then what would be a justification for the stakeholder who wants it way lower, what would you say to that stakeholder?</td>
</tr>
</tbody>
</table>
Dynamic epistemic network graphs

Computing epistemic adjacency matrices

The epistemic frame of a given profession, P, has elements $f_1, \ldots, f_n$, where each $f_i$ is some element of the epistemic frame of P. Further, the epistemic game based on P can be described as a series of activities about which we collect data, D.

For any participant $p$, we can look at $D^p_t$, containing the evidence that at time $t$ that player $p$ is using one or more of the elements of the epistemic frame of the profession P. To construct an epistemic network from data such as this, we create an adjacency matrix, $A^{p,t}$, for player $p$ at time $t$, recording the links between elements of the frame for which there is evidence in $D^p_t$:

$$A^{p,t}_{i,j} = 1 \text{ if } f_i \text{ and } f_j \text{ are both in } D^p_t$$

(1)

By representing the epistemic frame in use during a strip of activity as an adjacency matrix, we can use the tools of network analysis to examine the cumulative impact of strips of activity on a developing epistemic frame. We construct the cumulative adjacency matrix for player $p$, $F^p$, by summing the adjacency matrices $A^{p,t}$ from time $t = 0$ to the end of the game at time $t = e$ as:

$$F^p = \sum_{n=0}^{e} A^{p,n}$$

(2)

We use the same equation to compute $F^{p,t}$ the epistemic frame for player $p$ at any point of time $t$ in the game. That is, we sum the adjacency matrices for all of the strips up to time $t$ by:

$$F^{p,t} = \sum_{n=0}^{t} A^{p,n}$$

(2a)

If $A^{p,t}$ represents the epistemic frame in use for player $p$ during strip at time $t$, then $F^{p,t}$ represents the cumulative epistemic frame for player $p$ at time slice $t$. We thus represent the development of player $p$’s epistemic frame through a series of cumulative adjacency matrices $F^{p,0} \ldots, F^{p,e}$ where $e$ represents the end of the game.

We computed a series of epistemic adjacency matrices:

- one for each player’s in-game interactions in week three 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 and adjusted weighted density

Weighted density provides a measure of a frame’s complexity: the overall strength of association of the frame (Shaffer, et al. 2009). We compute $W(M)$, the weighted density of an epistemic network $M$ (either for a strip of time or a slice of frame development – that is, either for $A^{p,t}$ or $F^{p,t}$) by computing:

$$W(M) = \frac{\sum_{i,j} (M_{i,j})^2}{2}$$

(3)

We choose this measure rather than the more traditional network density function because network density measures only the number of links in the network as a percentage of the total links. Such a measure therefore does not take into account the weight of the associations in the network – which is a more useful measure of the strength of an epistemic frame. Computing weighted density from the squares of the associations weights the core of the network, representing networks with a small number of strong associations as stronger than networks with a large number of weak associations. We divide by 2 because the symmetrical nature of the adjacency matrix counts each linkage twice. We compute the root of the sum of squares to use links as the units of weighted density.

In order to compare weighted densities when there were a variable number of strips of time, 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 time.

Relative centrality

Relative centrality is a measure of the relative weight of an epistemic network’s constituent frame elements. First, we compute the sum-of-squares-centrality $C(f)$ or weight of an individual node $f$ in matrix $M$ as:
Finally, we compute the relative centrality \( R(f_i) \) of an individual node \( f_i \) in matrix \( M \) as:

\[
R(f_i) = \frac{C(f_i)}{C_{\text{max}}(M)}
\]  

Where \( C_{\text{max}}(M) \) is maximum node weight of any node in \( M \).

Statistical tests

\textit{T-test}

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 post-game interviews.

\textit{Correlation}

We correlated adjusted weighted density of the players’ 3rd week frames with the weighted density of their post-interview frames.\(^1\)

Results

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

Developing an epistemic frame

The matched pair questions that the players answered in the post-interviews contained more co-occurring frame elements than those answered in the pre-interview. 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; \( P < 0.01 \)). Figure 4 shows this change in weighted density:

These changes in weighted density corresponded to a qualitative difference in players’ development of the epistemic frame. 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 vague and general, without any mention of the elaborate process of learning about stakeholders’ needs, or working with colleagues to try and meet the needs of the stakeholders and the community as a whole. After the game, in a more elaborate response, the player refers to important elements of the epistemic frame of urban planning: research, collaboration, compromise, and justification all 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 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: Well yeah cause we gotta compromise, I can’t just like only want these people’s views to push through all the problems.
Mentor 2: Mmhm, so what are some of the ones you feel you might have to adjust? The taxes was one . . .
Player 1: Yeah taxes, um, I don’t know we have a lot of things in common kind of, well, Robert’s group doesn’t really care about greenspace, but um 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, um and I think everyone wants low crime. I mean, I don’t think anyone wants high crime . . .

The player is now prepared to compromise because she knows that planners do not only want to serve one group of stakeholders. She is ready to proceed directly to figuring 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, both in immediate conversations and in conversations as the game progressed. In terms of their relative centrality, the players’ frame elements followed the same sequence as those of the mentors (Fig 5):

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 the fourth, and the identity frame element 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 the 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 ($R = 0.6535737$, $P = 0.021$). Figure 6 shows the correlation between players’ in-game and post-game epistemic frames:

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.

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**Fig 5** Collective relative centrality of players’ and mentors’ epistemic frames throughout *Urban Science*.

**Fig 6** Correlation between players’ in-game and post-game epistemic frames.
**Discussion**

Mentoring relationships are widely thought to positively influence young people’s development. 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 in the game contributed to players’ development of the epistemic frame of urban planning through gameplay.

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 more dense. This change suggests that in answering the post-interview questions, players saw more connections between the skills, knowledge, identity, values, and epistemology of urban planning than they had in answering matched questions in the pre-interview. That is, the players of *Urban Science* began to develop a more complex epistemic frame in the domain of urban planning. 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 more professional way of thinking through 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 throughout the game. In those conversations, the players emphasized the same frame elements that the mentors did. 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, p. 88) argues, children ‘can imitate only that which is within . . . [their] developmental level,’ the players’ successful emulation of what the mentors were modeling suggests that the game activities of *Urban Science* 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 merely parroted, by the players, we compared the weighted density of the players’ frames in the third week of the game with that of their post-interview frames. The weighted densities of these frames were correlated. This correlation suggests that the epistemic frame that the players imitated during the game persisted after the game. That the players were able to reproduce the imitated frame after the game is evidence that the players of *Urban Science* internalized professional thinking to the extent that they no longer needed the mentors’ scaffold. The professional thinking used by urban planners went from being in the players’ zone of proximal development during the game *Urban Science*, to being within their actual development level by the time the game was finished. Vygotsky’s assertion, that ‘what a child can [do] with assistance today she will be able to do by herself tomorrow’ (1978, p. 87), was confirmed. While it is unclear exactly when the transformation took place, there is evidence that the players of *Urban Science* began to achieve some autonomy in their ability to think as professionals, and that their autonomy was derived from their interactions with mentors.

Vygotsky’s hypothesis presupposes that learning processes, such as the imitation of modeled behaviour, 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 do suggest that the imitation of modeled behaviour is one important step in the process of internalization. We have shown how mentors modeling professional thinking contributed to the *Urban Science* players’ development of epistemic frames. These epistemic frames were not just associated with the mentors’ guidance in that moment: they were internalized by the players. The players’ imitation of the mentors’ modeling is part of the process by which they learned to think like professional adults. What was modeled mattered, as the participants of *Urban Science* readily internalized the mentors’ way of working. Future work requires us to collect more data to conduct similar analysis of other aspects of professional-style mentoring in epistemic games.

A second finding of this study is that ENA 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. Network analysis is useful for measuring the relationships between things, and the complexity of those relationships. ENA measures the interrelated dimensions of expertise. One could imagine using ENA to study any game or other learning environment where success is contingent on the development of multiple interrelated dimensions. What those dimensions are in any given learning environment depend on the markers of expertise. Computer games, and in particular computer games grounded in valued real-world cultures like *Urban Science*, both provide real-life challenges for players and dynamically assess problem-solving; as Gee and Shaffer (2010) argue, computer games are ideal for 21st century assessment. In future studies, we hope to further examine the role of professional mentoring in epistemic games, and in particular, to use ENA to investigate the process by which players of epistemic games internalize epistemic frames.

**Limitations**

The results presented here have several limitations. First, this preliminary study only describes what a small number of students did while participating in 80 hours of the *Urban Science* epistemic game. As a result, this work provides insufficient grounds for making causal claims, nor does it by itself warrant immediately implementing epistemic games at a large scale. None of these results are more than suggestive, in the sense that this experiment is not a controlled study, conducted at large scale, and was not designed to distinguish individual differences in performance. On the contrary, this was a small-scale experiment, fundamentally qualitative in nature, designed to see whether this approach to education had promise for further development, and if so, to understand the mechanisms at work that would be tested more rigorously in further experiments. Follow-up work that looks at a larger volume of data is already underway, and we look forward to establishing more broad claims in future papers.

*Urban Science* is a simulation of one planning practicum and one type of planning. Not all urban planners focus on zoning, and not all planners follow the same steps that participants of *Urban Science* did. We feel, however, that *Urban Science* is an appropriately rigorous simulation of a particularly important aspect of urban planning.

During this iteration of *Urban Science*, all of the planning consultants were game researchers with limited urban planning experience. The planning consultants were minimally trained and were in the same place as the players at all times. The planning consultant to player ratio (1:3 in this case) is not a ratio that can be duplicated in most traditional school settings. Follow-up studies in which planning consultants interact with players remotely, and in which the ratio of player-to-mentor is much larger, are being conducted currently.

When looking at the relationships between the mentor and player frames, this study treated all mentors and players collectively. Further, the nature of how the planning consultants mentored the players was not observed. Future studies will include a closer analysis of the relationship between what the mentors are doing and what the players are learning. For example, specific mentoring strategies, such as asking certain types of questions or referring players to other resources, might tend to work differently for different players, or differently during different activities, or at different stages of the game.

Finally, ENA is a new method for understanding the development of an epistemic frame. As such, we expect to develop it in ways that allow us to better test significant events in player frame development. Spikes in the relative centrality of specific frame elements for players during certain activities will be more closely analysed. Also, frame density is a proxy measure in this study; we would like to link it to practical demonstrations of thinking in the domain of urban planning. In addition, the frame elements coded in this study are coarse-grained. Future studies will seek to measure frame elements more specific than the basic skills, knowledge, identity, values, and epistemology.

Despite these limitations, however, the results here suggest several implications for the larger community of 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 also develop the ability to think as urban planners themselves. The persistence of the modeled epistemic frame suggests that the frame, once developed, constitutes a professional vision that can be applied in a range of situations in the world.

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Note

1The data for one player’s third week consisted of only one interaction, so that player was removed from the test.

References


