*Chapter*

# DEPENDENCY-CENTERED DESIGN AS AN APPROACH TO PEDAGOGICAL AUTHORING

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## ABSTRACT

In this chapter, we take the first steps toward a theory of dependency-centered design that is specifically concerned with how to support teachers in authoring games and other complex pedagogical simulations. We argue that complex pedagogical simulations such as virtual internships bring a new challenge: what we call the paradox of pedagogical simulations. The stronger and more immersive a pedagogical simulation is, the weaker and more detached the teacher can become. To investigate this phenomenon, we conducted a case study of one educator using an authoring tool create a new immersive teaching simulation. We examine this educator's work to understand how games and complex pedagogical simulations change the relationship between the planned and the enacted curriculum. Our results suggest that we need to rethink the relation between authoring, modifying, and teaching with pedagogical simulations, and that tools informed by *dependency-centered design* can addresses the paradox of pedagogical simulations, supporting the agency of teachers by allowing them author or modify pedagogical simulations effectively.

**Keywords:** pedagogical authoring, dependency-centered design, simulations, virtual internships

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## INTRODUCTION

In this paper, we examine a central, yet understudied, challenge in the development and use of games and simulations as learning environments - what we call the *paradox of pedagogical simulations*. The challenge is that the more *immersive and engaging* a pedagogical simulation is, the more *detached* teachers who use the simulation can become. Thus, what makes a simulation or game more effective at teaching students potentially makes a teacher less effective. We argue that because teachers play a critical role in students' development, this paradox forces us to rethink the relationship between authoring and teaching with pedagogical simulations.

Immersive environments like educational games and simulations provide powerful educational opportunities for students. They model aspects of the real world (or of imagined worlds) that are too difficult, dangerous, or complex for students to experience on their own. Such environments frame students as characters in a narrative, enacting a role in which they investigate and solve some meaningful problem. In other words, games and simulations create a fictional world that motivates students to explore some pedagogically important scenario. As a result, students have the opportunity to develop situated understanding of abstract and sophisticated concepts through exploration, experimentation, and reflection. For example, *virtual internships* (Shaffer, 2007) allow students to play the role of interns at fictitious companies where they work on simulated, real-world problems in domains like engineering and urban planning. And in the simulation Quest Atlantis, students are positioned as scientists, doctors, reporters, and mathematicians in a fictional world trying to save the civilization of Atlantis (Barab et al., 2009; Hickey, Ingram-Goble & Jameson, 2009).

Over the past two decades, studies have shown that learning environments like these have the potential to improve and transform teaching and learning (Clark et al., 2009; Dondlinger, 2007; Honey & Hilton, 2011; Squire, 2011; Vogel et al., 2006; Wilson et al., 2009). Despite this pedagogical utility, however, the complexity and sophistication of immersive learning environments makes it difficult for teachers to create their own simulations or to modify existing ones to meet their needs (Shaffer, Ruis, & Graesser, 2015). There are some examples of authoring tools that can support teachers in this authoring work but it can be difficult for teachers to use such tools effectively (Ainsworth & Grimshaw, 2004; Major, Ainsworth & Wood, 1997).

This presents a challenge because effective teachers spend a great deal of energy creating and modifying curricula to meet the specific needs of their students and local context. For example, when making a lesson plan, teachers may curate the content by selecting particular sections of a material such as chapters of book or subsets of problems. Similarly - and in some ways more importantly - teachers also augment, rearrange, and change the content of their class in the moment. They add explanations, change or adapt questions and assignments, add probing or clarifying questions or simplify the course material depending on students' response to it. In other words, there is a continuous dialectic between planning and enactment that teachers use to tailor existing pedagogical materials to the needs of their students.

On one hand, then, immersive environments can be powerful pedagogical tools. On the other hand, teaching situations vary depending on the needs, background, and interests of students, and on the structural, material, and temporal constraints of the classroom. Teachers need to be able to author and modify curricular materials to suit the needs of their students

and classrooms, but this is hard for teachers to do when teaching with immersive environments.

In other words, pedagogical simulations shift the balance between planning and enactment in the work of a teacher. Pedagogical simulations constrain the space of teacher action during their use in a classroom because the technical features, framing, and narrative that make the virtual world pedagogically powerful make it difficult for teachers to adjust moment-by-moment to conditions in the classroom without breaking the fictional world of the simulation. A teacher cannot (or should not) act in ways that break the fiction that students are real participants in a simulated experience; therefore, there are only some pedagogical choices a teacher can make while the simulation is running that are consistent with student engagement in the environment. As a result, teachers who use pedagogical simulations have to make decisions when *planning* their curriculum that with more traditional materials might happen during the *enactment* of the curriculum.

In this paper, we argue that both the complexity of pedagogical simulations and the associated shift from enactment to planning require us to develop a theory of *pedagogical authoring* particular to these learning environments. To that end, we present and discuss a case in which an educator uses an authoring tool to create a pedagogical simulation, and we use this case as an opportunity to examine the paradox of pedagogical simulations in action. Although the example we provide here is limited to a single case, this approach is useful because it provides rich and detailed information on an understudied context. Insights from this approach will begin to build our understanding of how working with immersive learning environments can affect the ability of educators to act effectively. Moreover, the insights we gain here can suggest lines of inquiry, design principles, and hypotheses for future study.

# THEORY

## Pedagogical Design

Scholars in the field of Learning Sciences (see, e.g., Brown & Campione, 1996; Papert, 1980; Shaffer, 2002) have long argued that effective learning environments function as *coherent systems*. That is, the different activities, expectations, and interactions (a) among students and (b) between teachers and students that (c) use tools, technologies and resources, work together to help students develop some desirable set of skills, understanding, and habits of mind.

This coherence of pedagogical systems has at least three sources. One source of coherence in a learning environment is the existence of underlying ‘‘principles of learning’’ (Brown & Campione, 1996). Curriculum designers often articulate some set of principles, and then use that as a framework for deciding what activities, assessments, and pedagogical moves to include in the learning environment. For example, the zone of proximal development suggests that learning environments should include activities for students that are beyond their capability to complete alone, but within their capability to complete with assistance (Jumat & Tasir, 2014). The constructionist principle of learning by building suggests that educational designers should develop microworlds that facilitate construction

processes among learners (Kafai & Resnick, 1996; Papert 1980; Resnick, 1994; Tekinbas et al., 2014; Hanghøj et al., 2014.)

However, principles of learning are not sufficient for designing a coherent learning environment because they tend to both underspecify and overspecify the conflicts and decisions involved in actual teaching (Biesta, 2015; Skott, 2004). That is, there are always aspects of a pedagogical design problem that cannot be decided based on principles alone, but also because there are multiple principles of learning that can apply in any given learning context, principles often provide conflicting or contradictory advice to designers.

One way that this problem is addressed in practice is to work with *exemplars*, or existing examples of successful pedagogical activity, such as lesson plans or case descriptions of teaching (Stigler, 1998). Situations and practices outside of school can also act as exemplars in the sense that they can provide guidance as to what activities, interactions, and structures might be effective for students. For example, Shaffer (2007, 2012) argues that the way professional accountants, architects, engineers, journalists, lawyers, and doctors are trained can provide models for virtual internships in which students work on real-world problems in a fictitious setting. In other words, learning environments are built from some combination of *explicit principles* of sound pedagogy and *existing exemplars* of effective and valued practices.

For any learning environment, there has to be some basis by which these principles and exemplars are chosen. If an environment is to be effective, there has to be an alignment between the content and practices of the learning environment and desired student outcomes. The idea of aligning educational means and ends goes back at least to Dewey (1916). More recently, Biggs (1999) suggested that good pedagogical design is explicit about the connections between activities, goals, and assessment; and Pellegrino (2014) argues that assessment should be designed with its purpose in mind, whether that be to assist learning, measure achievement, or evaluate a program.

While these high level alignments are crucial, there are also finer grained relationships between the specific pieces of content that teachers and students interact with in the learning environment. For example, the instructions, problems, rubrics, and feedback for a particular assignment are dependent on one another and the relationship between these elements must be maintained. If the rubric by which an assignment is changed, the instructions and feedback have to be adjusted to match. There are thus a set of *pedagogical dependencies* that help to align the activities and goals of a curriculum.

In summary, the process of coherent pedagogical design has at least three critical components:

- Some set of *pedagogical principles* that frame the activities. Such principles both suggest appropriate pedagogical choices and connect activities and learning outcomes. These principles often support specific interpretations of learning theories to educational activities.
- Existing *exemplars* that make up concrete instances of the pedagogical design. Such exemplars act as paradigmatic examples and allow conversation and imagination about future pedagogical scenarios.
- A collection of *pedagogical dependencies* that allow the designer to align the learning outcomes activities suggested by pedagogical principles and exemplars.

As the complexity of the pedagogical content grows, in general, so does the difficulty in managing these components. In the case of pedagogical simulations, this complexity rises quickly: the actions students can take, objects they can manipulate, characters with which they can interact, and places they can explore multiply to produce a dizzying array of possible pathways. The dependencies among the aspects of the virtual world become both harder to track, and it becomes even more critical to maintain the alignment between student activity and the goals of instruction (Westera et al. 2008).

This suggests that creating immersive digital learning environments requires tools that are adapted to manage pedagogical principles and dependencies as well as exemplars. As Shaffer and colleagues (2015) argue, effective pedagogical authoring tools must allow authors to create and modify digital learning environments while ensuring that the learning environment remains "pedagogically sound" (pg. 181). In other words, authoring tools must help authors manage the essential components and constraints inherent to the learning environment.

There are a number of existing technologies for creating immersive digital learning environments. There are game development platforms such as *Unity*[1] and *Game Maker*[2], and a well-established tradition of adapting and extending commercial games: a process often referred to as "modding." Players use modding tools to create new content and scenarios for existing game systems. However, none of these platforms are designed to account for the specific challenges of pedagogical design[3].

Researchers have developed authoring tools that let curriculum designers develop virtual learning environments. For example, authoring tools for intelligent tutoring systems (ITSs), such as Cognitive Tutor Authoring Tools (CTAT) and Authoring Software Platform for Intelligent Resources in Education (ASPIRE), and the AutoTutor Script Authoring Tools (ASAT and ASAT-Lite), have been used to create environments for student learning in a number of domains (Vincent Aleven et al., 2009; Mitrovic, 2012; Mitrovic et al., 2009; Hu et al., 2009; Nye, Graesser & Hu, 2015; Cai, Graesser & Hu, 2015).

While tools such as these are designed to accommodate complex technical features, they do not account for environments that situate students within a complex narrative. Authoring tools that account for complex narrative structures do exist such as StoryTec, Scenejo, and The Scribe Authoring Tool (Mehm et al., 2009; Spierling, Weiß, & Müller, 2006; Medler, & Magerko, 2006). However, these tools are designed for settings in which students work with a small number of conversational agents as opposed to multiple agents or teams of other students.

In what follows, we describe the process of designing pedagogical simulations that balance pedagogical principles, exemplars, and pedagogical dependencies as *dependency-centered design*.[4] We argue that dependency-centered design is a crucial lens for

[1] See https://unity3d.com/

[2] http://www.yoyogames.com/gamemaker

[3] Of course, Learning Management Systems such as Moodle and It's Learning do allow teachers to create environments under pedagogically framed constraints. But to our knowledge there exist no editor of game oriented learning designs that takes pedagogical alignment seriously.

[4] Some readers will doubtless be familiar with the similarity of this term to Mislevy and colleagues' (2003) *evidence-centered design*. Their approach looks at three "models" of the learning process: the *student model*, or characteristics of the student we want to assess; the *evidence model, or* evidence and tools that will provide support for the claims in the student model; and the *task model*, or activities students will complete to elicit that evidence. The core idea in evidence-centered design is that the student model, evidence model, and task model must be aligned for the assessment to be coherent. Where Mislevy and colleagues focus specifically on

understanding the work of curriculum designers who wish to author and adapt pedagogical simulations to fit within their own curricula or align them with changing standards.

Clearly though, the success of any tool to support dependency-centered design depends, at least in part, on whether and how it is compatible with the practices educators use to design pedagogical content. In particular, it has to accommodate the ways teachers plan their work in the classroom.

## Teaching

Teachers already do pedagogical authoring. They create lesson plans, and then enact those plans in the classroom with their students. Remillard (2005) describes this as a distinction between the *enacted* and the *planned* curriculum. This interaction is, of course, critical to understand the relationship between the *design* of materials—including immersive simulations—and their actual *use* in a classroom setting.

Priestley, Biesta, and Robinson (2012) suggest that one way to analyze the interaction between educators and a curriculum is through the lens of *teacher agency*. These authors base their work on that of Emirbayer and Mische (1998) who describe the notion of agency as a configuration of influences from past, orientations toward the future and engagement with the present, (pg. 963).

The past-oriented dimension includes prior experiences include their personal history, educational experiences, and pedagogical experiences. This dimension refers to how prior experiences forms conception and gives stability and meaning to situations. Thereby allowing action. In the case of teaching, experience is very important partly due to the complex space of potential situations that can occur in any teaching situation.

The future-oriented dimension includes teacher's short term and long term goals for the students and for their teaching. This dimension has to do with the goal directed nature of human agency, wishing a particular outcome and thinking forward is part of what constitutes and allows action. Projection and teaching are clearly related since teachers often aim for certain values, skills, and knowledge to be developed within their students; they think about both how these skills would be enacted by students and about the pathway along which students can get to that point.

The present, or action-oriented, dimension includes the cultural, structural, and material conditions to which teachers respond, and the way in which teachers make pedagogical decisions. Here, the past and the future meet in actual choices of how to respond to particular situations.

In other words, teacher agency can be conceptualized in terms of the past, future, and present aspects of teacher work—what Emirbayer and Mische call the *iterative*, *projective*, and *practical-evaluative* dimensions of teacher agency:

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the alignment required to construct valid assessments, here we extend this concept of alignment to pedagogical authoring in general, arguing that learning environments are guided by theories of learning and by exemplars, each of which suggest activities that will support some set of learning outcomes. These components must be chosen so as to be complementary to ensure a coherent learning environment—that is, they must be orchestrated or aligned with one another.

- The *iterative (past-oriented) dimension* is a teacher's ability to activate prior experience when interacting with curricula.
- The *projective (future-oriented) dimension* is the teacher's ability envision the future state of his or her class.
- The *practical-evaluative (action-oriented) dimension* is the process by which teachers make judgements about what to do in the classroom.

Emirbayer and Mische suggest that these dimensions play a role in all concrete actions, but that some dimensions may contribute more or less in a given action. Thus, they see agency as "chordal triad…within which all three dimensions resonate as separate but not always harmonious tones." (pg. 972).

Prior work on teacher agency mainly focuses on how agency works as a teacher enacts an existing curriculum in a classroom setting. Here, however, we propose to use this same concept of agency to understand what happens during the development of an immersive simulation designed for use in the classroom. Consequently, our interpretation of the dimensions of teacher agency must accommodate this shift in context. In particular, in the context of curricular planning, the practical-evaluative (action-oriented) dimension cannot refer to actions taken by the teacher *during a teaching situation* to create a particular student experience, but rather to actions taken *prior to the teaching situation* that will define and constrain the subsequent student experience.

In what follows, we use a case study of one educator creating one particular pedagogical simulation - a *virtual internship* - using one specific authoring tool designed to help users manage the dependencies inherent to these environments. Our aim is to understand whether and how dependency-centered design facilitates teacher agency in the creation of an immersive digital learning environment. Specifically, we use this case to look at the interactions between pedagogical principles, dependencies, and exemplars and the iterative (past-oriented), projective (future-oriented), and practical-evaluative (action-oriented) aspects of teacher agency.

# METHODS

## Setting: Virtual Internships

Virtual internships are online pedagogical simulations of professional practice (Shaffer 2007). These simulations build upon the idea that learning is fundamentally a process of enculturation through participation in authentic activity (Brown, Collins, & Duguid, 1989; Shaffer 2012). Here, authentic activity includes the kinds of activities in which members of a domain or profession participate. For example, urban planners research community interests, develop zoning plans, and write land-use proposals. One way that students can participate in these kinds of authentic activities is by participating in a practicum, such as an internship.

Virtual internships are online simulations of such practicums that allow students to participate in simulated versions of authentic activity. In virtual internships, students play the role of interns at fictitious companies where they engage in realistic professional work. In the virtual internship *Land Science*, for example, students work in teams to develop a new land-

use plan for the city of Lowell, Massachusetts. During the internship, students review research briefs, survey community stakeholders, and use a GIS mapping tool to model the effects of land-use changes on various environmental and socio-economic indicators. At the end of the internship, students write a formal proposal in which they justify their planning decisions.

Virtual internships such as *Land Science* are complex environments with many interdependent components. The activities in virtual internships take place in *WorkPro*, an online productivity suite for these simulations. Students can access WorkPro from any computer or tablet with Internet capabilities. It includes professional communications tools such as email and chat, an electronic notebook for recording work, and all the tools and resources that students need to complete the internship. Through WorkPro, students interact with each other, as well as computer-generated *non-player characters* (NPCs), such as their *supervisor* and a *mentor*.

In practice, these NPCs are controlled through a combination of artificial intelligence and the actions of human *domain-managers* (DMs). Students experience the content of virtual internships through a series of activities called *rooms*. In each room, the DM sends an overview email from the supervisor to the students. This email describes the tasks they should complete with their team, points them to resources and tools within the internship, and provides instructions for completing *deliverables* that they must submit to their supervisor for review. As students complete their deliverables, they can get assistance from their mentor via WorkPro's chat interface. To chat with students, the DM can send pre-scripted or original chats in the voice of the mentor. Students also have access to examples of satisfactory work, as well as resources such as research documents, that they can use to complete their deliverables. After students submit their deliverables, the DM evaluates them using a rubric. Based on these evaluations, a feedback email from the supervisor is automatically generated and sent to the student. Once students have been given a chance to make revisions to their deliverables, the DM sends the overview email for the next room.

Each of these pieces of content—deliverables, overview emails, pre-scripted chats, rubrics, feedback emails, and so on—are related to one another in a particular way and must be present for virtual internships to operate as intended. For example, (see Figure 1), if a particular deliverable were to not have a corresponding instructions in the overview email, students could become confused. And if a deliverable were to lack a rubric or pre-scripted feedback text, a mentor would find it difficult to assess student work. Thus, virtual internships contain a number of dependencies that must be managed by authors when they create or modify content.

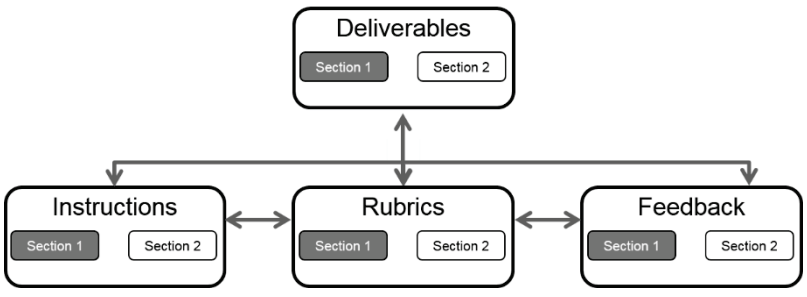


Figure 1. An overview of the pedagogical dependencies in the virtual internship environment.

## The Virtual Internship Authoring Tool

To allow authors to create new virtual internships or modify existing ones, we developed the Virtual Internship Authoring Tool (VIA). The VIA interface contains templates for the content of virtual internships—deliverables, emails, and so on. These templates are comprised of separate text-fields for each component of the content. Authors who use VIA may choose between two initial states of the tool. First, they can begin using VIA as a blank-template. In other words, no pre-existing content would populate the text fields. Alternatively, authors can begin using a version of VIA pre-populated with the content of an existing virtual internship, such as *Land Science*.

VIA has three main features designed to help authors manage the dependencies in virtual internships. First, the Dependency View collects content together for editing and helps authors visualize the dependencies (see Figure 2). In virtual internships, the primary dependencies among the content exist within deliverables. That is, the items that participants submit in each room have separate sets of content associated with them that should exist in the proper alignment. Thus in VIA, the dependent content for each deliverable is collected together, such as details about the deliverable that populate the overview email and assessment information for the mentor, and represented in a hierarchical structure. In this view, authors can navigate through the structure and use text fields to edit, delete, or create content.

Second, the Compiled View helps authors visualize virtual internship content in context by collecting content across deliverables (see Figure 2). For example, VIA compiles the background information and instructions for each deliverable into the "Overview Email" section of The Compiled View.

Finally, the Compiled and Dependency Views are coordinated—that is, the actions that authors take in one view have consequences for the other. For example, if an author clicks content in the Overview Email section of the Compiled View corresponding to the instructions for the third deliverable in the room, they are automatically navigated to the text field in the Dependency View containing that content. The link between these two views is highlighted by a connector, seen in Figure 2. Moreover, this relationship is also bidirectional in the sense that a click in the Dependency View will also navigate the author to that content's location in the Compiled View.

To investigate whether such a tool allows educators to effectively author pedagogical simulations while facilitating their agency, we conducted a case study of one educator who recently used VIA to develop a new virtual internship.

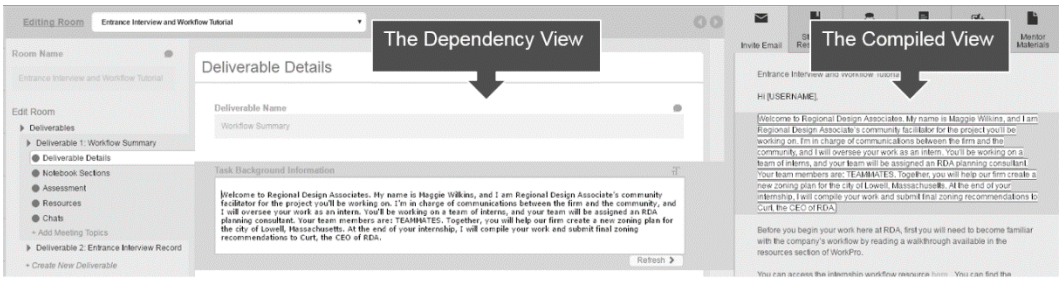


Figure 2. Key features of the VIA interface.

## Data Collection and Analysis

The focus of this case study, Jerry (a pseudonym), is a professor of education with a background in curriculum and instruction. While Jerry has had experience working with educational technology, he does not consider himself to have expertise in computer programming. At the time of this study, he was familiar with the concept and pedagogy of virtual internships, but had neither participated in one nor implemented one in a classroom.

**Table 1. Definitions and examples of the codes used in this analysis**

| Code | Definition | Example |
|---|---|---|
| Pedagogical principles | Discussing the pedagogical influences used to frame the activities of the new virtual internship | Yeah, so *it was modeled on actual interns.* |
| Exemplars | Discussing the use of or modification of content from a pre- existing virtual internship during while authoring the new virtual internship. | [in] some of the rooms I didn't have to edit the text very much so *I was basically changing out RDA associates or whatever* it might be with the other names or changing a few little details. The name of the deliverable might be different or something like that. So in some cases it made my job a lot easier to be able to both see the different pieces in the dependency view but also just *to be able to have that text there to edit.* |
| Dependency Features | Discussing the use of VIA features designed to help manage dependencies such as the Dependency View and the Compiled View. | there's a stronger *relationship between the compiled view and the dependency window* because [with] those you're seeing the direct connection of where one goes in the other. |
| Projective (future-oriented) | Discussing goals or intentions for the virtual internship content. | Yeah, because in the U.S. this has blown up in terms of what it means to be in politics, it's all about sound bytes and getting airtime because it's all about fundraising. So it's about the role of money in politics, really, is what it comes down to. So in this case *I didn't want … make everyone so cynical about politics, so I'm trying to balance the line a little bit too*. |
| Iterative (past-oriented) | Discussing prior experiences and pedagogical situations that influenced the creation of the virtual internship | I was able to look at it when I was up there with you all but *I didn't actually experience sort of the whole internship or see the mentors in action* or some of that. I think if I had a little bit more of that *it might have helped a little bit.* |
| Practical Evaluation (action-oriented | Discussing judgements about how students will interact with the virtual internship content in varying classroom conditions | *one of the things I'm a little concerned about still is the levels of some of the materials* that we're finding and making decisions on what data, readings, things like that can we use that exist and what things are we gonna have to recreate … versions, *for them to use that are at a more appropriate reading level or more accessible or that won't take too long.* |

To collect information on Jerry's authoring process, we conducted a semi-structured interview in which we discussed his authoring process in detail, including how he generated the concept for his virtual internship and how he used VIA to author its content.

We coded the transcript of the interview using six discourse codes. Three of these codes correspond to the components of dependency-centered design, as they are represented in VIA. The remaining three codes were informed by the work of Emirbayer and Mische (1998) and Priestly and colleagues (2012) and correspond to the dimensions of teacher agency discussed above. Two of the authors applied this coding scheme to the entire transcript using a process of social moderation (Adie et al. 2012), meaning that both coders coded all excerpts and resolved any differences.

# RESULTS

## Background

During our interview with Jerry, he described the authoring process for his new virtual internship, *PurpleState*, in detail. His goal was to develop a simulation that educates students on how media is used by political groups to influence the opinions and decisions of citizens. To meet this goal, Jerry created a virtual internship where high school students play the role of interns at a strategic communications firm.

During *PurpleState*, students' main task is to develop a media campaign for a special interest group about the issue of fracking. Fracking has many economic benefits, but is also associated with hazardous environmental impacts, such as water contamination, air pollution, and triggered seismic activity, and is thus a controversial political issue. Through designing a media campaign for special interest groups that are either for or against fracking, Jerry hoped that students would learn about both sides of a controversial issue, the political use of media, and how to apply strategic communications strategies in their own civic action and political engagement.

To design *PurpleState*, Jerry consulted with one of his former students who works at a large public relations firm. Together they outlined the structure of *PurpleState* by identifying the typical tasks that interns do at a strategic communications firm, the roles they have, and the information they have access to. In total, Jerry's internship consisted of 11 rooms.

From our interview analysis, we identified three main ways in which the components of dependency-centered design interacted with Jerry's teacher agency during his authoring process. In the next sections, we discuss each of these in turn. Although each section highlights a different dimension of teacher agency, as Emirbayer and Mische (1998) argue, all dimensions play some role in concrete teacher actions. However, for clarity's sake we handle the dimensions separately and explore the complex connections between them in the discussion section of the paper.

## Projection (Future-Oriented) and Pedagogical Principles

As described above, virtual internships simulate real professional practice in an effort to teach students through authentic activity. Authoring a virtual internship thus requires some knowledge of the kinds of activities real professionals do in a given domain. To understand the actual practices of strategic communications interns, Jerry consulted his former student who works with interns at a public relations firm. During the interview, Jerry discussed two ways in which he based his virtual internship on actual intern experience:

> one is "What did [my former student] ask his interns to do to basically train them to get them ready to work on a project?" … And then the second piece was, "If you had interns working on a project like this, what types of things would you actually ask them to do?

He went on to say that many of the activities he discussed with his former student were "built into the simulation," including activities where students audit media to find out which political groups are for or against a controversial issue, as well as tasks where they examine polling data. Thus, by incorporating the activities of real strategic communications interns into his virtual internship, Jerry adopted a core *pedagogical principle* of virtual internships—namely, that students learn through participating in authentic activity.

Jerry chose this particular focus because, as he described during an interview, his idea for *PurpleState* came out of a desire to help students develop into "democratic" and "media-savvy" citizens. In particular, he wanted students participating in this virtual internship to understand how media is being used by politicians and political groups to "influence or get them to participate in certain ways." In addition, he hoped that students would be able to apply what they learned in the simulation to situations in the real world, saying that he wanted students to be able to "use some of these same strategies for their own taking action." In other words, as he authored his virtual internship, Jerry envisioned the particular goals he had for students. Thus, he enacted the projective (future-oriented) dimension of teacher agency.

These comments by Jerry suggest that there was a connection between the projective (future-oriented) dimension of Jerry's agency and the pedagogical principles of virtual internship. These two elements of the design process were co-constructed in his authoring actions. From Jerry's comments on the activities he planned for students in his virtual internship, we see that the pedagogical principles that Jerry adopted acted in concert with the projections, or goals, he had for students.

## Iteration (Past-Oriented) and Exemplars

When authoring in VIA it is possible to start with either the content of Land Science pre-loaded, or from a blank template. When Jerry started his authoring process, he used the blank template version of VIA. However, he quickly found it difficult to work with this version. He said that, "early on when I went in and just looked at sort of the blank [template], it's extraordinarily overwhelming because of all the small components to what it is."

Instead of continuing with the blank template, he began working from the content of the *Land Science*, modifying it as he went along. He said that it was "easier for [him] to conceptualize it with the example there than to create it from blank [text fields]." Jerry talked

about two main ways in which the content of *Land Science* helped him. First, it helped him with the high-level structure of his content:

> I saw sort of how that [Land Science] was structured, and we pulled from this information about the interns and what [my colleague] had his folks do and made that into an outline basically by room.

That is, Jerry describes how he used the structure of *Land Science* in combination with the information about actual internships from his colleague to "outline" the content of his virtual internship. Hence, the structure of *Land Science* served as an *exemplar* that Jerry could use to structure his own virtual internship.

In addition to helping him structure *PurpleState* at a high-level, *Land Science* also helped Jerry construct the more fine-grained content of his virtual internship:

> So I think in particular the examples that were in there were really helpful in thinking about the language and…how the tasks were structured within there, how the notebooks were structured, how… the facilitated discussions are structured.

The content of *Land Science* helped Jerry manage particular dependencies in his own content, namely, the tone or "language" of the text and the structure of tasks, notebooks, and facilitated discussions.

We can see the influence of this exemplar by comparing the content of *PurpleState* to the corresponding content from *Land Science*. Table 2 below shows a sentence-by-sentence excerpt of one paragraph taken from *PurpleState* and *Land Science*. This excerpt is from the overview email in first room of both internships.

**Table 2. A comparison of two overview email excerpts, one from *Land Science* and one from *PurpleState.* Bold text is shared verbatim between the excerpts. Italicized text is content related to the narrative of the specific virtual internships**

| *PurpleState* Excerpt | *Land Science* Excerpt |
|---|---|
| **Welcome to** *PurpleState Solutions, Inc.* | **Welcome to** *Regional Design Associates.* |
| **My name is** *John,* **and I am** *PurpleState's Account Executive for the Energy and Environmental Policy division in charge of* **the project you will be working on.** | **My name is** *Maggie Wilkins,* **and I am** *Regional Design Associate's community facilitator for* **the project you'll be working on.** |
| **I will oversee your work as an intern.** | I'm in charge of communications between the firm and the community, and **I will oversee your work as an intern.** |
| **You will be working on a team of interns, and your team will be assigned** *a PurpleState Account Manager.* | **You'll be working on a team of interns, and your team will be assigned** *an RDA planning consultant.* |
| **Together, you will help our firm** *design political media campaigns to propose to our clients.* | **Together, you will help our firm** *create a new zoning plan for the city of Lowell, Massachusetts.* |

In bold, are the pieces of the original *Land Science* excerpt that remained verbatim in the corresponding *PurpleState* excerpt. In italics, we have the text related to the narrative of the

internship, that is, the names of the fictional companies, supervisors, and mentors that Jerry translated from *Land Science* to *PurpleState*. The remaining, standard, text is the content that does not overlap between the two excerpts. Here, we can see that Jerry (1) used pieces of text from *Land Science*, (2) translated text from *Land Science* related to the narrative of the internship, and (3) created original text. We found evidence of these three actions throughout the 11 rooms in *PurpleState*; however, the amount of borrowed, translated, and original text varied substantially across rooms.

Later in the interview, Jerry discussed how crucial the *Land Science* exemplar was to his authoring process:

> Without those examples it would have been really hard to come up with on my own, unless I had a classroom version I had already used for years or something [I] was turning into a virtual version.

In other words, although Jerry lacked prior experiences that could have helped him author a virtual internship, such as having a traditional "classroom" version that he could adapt into a simulation, he was able to use the *Land Science* exemplar to help him create the content of his virtual internship and *act as if* he had prior experience doing so. Thus, Jerry's authoring process suggests that he used an exemplar to enact the iterative (past-oriented) dimension of teacher agency.

## Practical Evaluation (Action-Oriented) and Pedagogcial Dependencies

VIA was designed with particular hypothesis in mind: that managing the dependencies in virtual internships would be integral to the pedagogical authoring process. Thus, VIA included several features to help with this management. During our interview with Jerry, he talked about the importance of these features and how he used them during his authoring process.

For Jerry, the Compiled View and, in particular, its representation of the overview email, was important for guiding his thinking and helping him decide how to proceed in the authoring process. He said, "I usually work through the [overview] email first ... because that's sort of outlining the different pieces of the tasks that I want students to be able to do."

Once he was working within the Compiled View, his authoring process became structured in a very particular way:

> In my mind, I already have an outline I'm working from in terms of what I wanted each room to do generally speaking and some of the specifics, so when I look at the [overview] email I know what I want to go in the different parts of the email and then, so I'm clicking on that section and then in the dependencies section basically putting in that text.

Here, Jerry describes taking his goals, "what [he] wanted each room to do", looking at the overview email that initially contained *Land Science* content, and using its content and structure to decide where he wanted to put his new content. Next, he proceeded by "clicking on that section" of the email that he wanted to edit and entering his new text in the "dependencies section" or the Dependency View.

In the above comment, Jerry refers to the link between the content in the Compiled View and the Dependency View. As described above, these representations are coordinated in the sense that when an author clicks content in the Compiled View, they are automatically navigated to where that content can be edited in the Dependency View. Once in the Dependency View, the author can see additional content that is dependent on what was originally clicked.

Jerry found that this feature of VIA helped him author his content more easily, saying that once he clicked on content in the Compiled View "it was easy enough in the dependency piece just to change that language in the other parts as I went…" In other words, once Jerry was working in the Dependency View, he found it easy to continue editing the dependent content that was present.

This relationship between the Compiled View and the Dependency View also helped Jerry to author content that he may have forgotten to include:

> Having the absentee piece in there is probably really important. It's not the first thing that was coming to mind as I was designing this, which is why it's probably important to have it prominently there, because otherwise I would have forgotten about it.

Here, Jerry talks about how content dependent on what he originally clicked in the Compiled View was presented in the Dependency View. In particular, he references the text field that includes task instructions for absent students, the "absentee piece". He says that having this piece presented to him was "really important" because if it had not been there, he "would have forgotten about it." Thus, this feature of VIA helped Jerry manage a critical dependency in virtual internships: if you give a task to students, you must also provide instructions for students who are absent.

The above quotes suggest that these *dependency features of VIA* helped Jerry (1) outline the main tasks for students (2) coordinate between the Compiled View and the rest of the environment, and (3) include all the details necessary for the environment to be coherent. In other words, these features helped Jerry manage his process of making pedagogical decisions.

Jerry described the Compiled View as the "primary place that's helping [him] understand where sort of the big pieces are." These "big pieces" all relate to how students would experience the internship. And in that sense, the dependency features helped Jerry simultaneously author the various elements of the internship and decide on how these elements would act together during the actual student experience.

In other words, while Jerry was editing the specific content of the curriculum the features of the VIA system helped him consider students' actions and how he wanted the immersive simulation to respond. His decision making process illustrates the practical-evaluative (action-oriented) dimension of teacher agency, or the process by which teachers make judgements about actions to take in the classroom in response to varying conditions. However, in Jerry's case, these judgements were made prior to a classroom situation and with a tool designed to highlight and maintain pedagogical dependencies in the simulation.

## DISCUSSION: DEPENDENCY-CENTERED DESIGN AND THE PARADOX OF PEDAGOGICAL SIMULATIONS

Our analysis thus suggests three ways in which the components of dependency-centered design interacted with Jerry's agency as he authored *PurpleState*. Coherent learning environments are guided by pedagogical principles that suggest particular pedagogical choices, student activities, and learning outcomes. In the case we presented here, Jerry used the pedagogical principles underlying virtual internships in ways that activated the projective (future-oriented) dimension of his agency. The pedagogical principle related to the virtual internship (e.g., engaging learners in work like authentic experiences), informed the types of activities he chose to include in the environment. In other words, Jerry used this pedagogical principle to help him envision desirable actions for students in future teaching situations. Moreover, the activities that Jerry envisioned were linked to the objectives he had for the students' learning.

Developing and modifying coherent learning environments can also be informed by exemplars that model effective pedagogical activities, interactions, and structures. In Jerry's case, *Land Science* acted as an exemplar that helped him structure the content of his own virtual internship and author it more efficiently. Of course, Jerry's authoring process was also informed by his own prior experience as an educator at some level, as the iterative (past-oriented) dimension of the teacher agency framework suggests. However, in Jerry's case, he lacked prior experience creating this type of content and translating it to the context of virtual internships. According to Jerry, this lack of prior experience was precisely why having *Land Science* as an example to work from was so important. Thus, our results suggest that the exemplar Jerry used, when combined with is actual prior classroom experience using other curricula, acted as a substitute for prior experience that have made his authoring task easier. This suggests that the use of an exemplar can help teachers activate the iterative (past-oriented) dimension of their agency while authoring novel pedagogical simulations.

A third component of coherent learning environments is the alignment between the difference facets of the simulation itself as it interacts with and responds to students. To create this alignment, Jerry was required to manage the dependencies that exist within the pedagogical content that students interact with during teaching situations: the materials students work with, the instructions and feedback they receive, the criteria with which they are assessed, and so on. Jerry managed the dependencies in his virtual internship using particular features of the authoring tool VIA. While he was using these features, he was making decisions about how this pedagogical content would unfold in and respond to future teaching situations. Thus, we argue that in the case of this immersive simulation, the practical-evaluative (action-oriented) dimension of Jerry's teacher agency was shifted from its usual position in the moment-by-moment highly-focused activity of working with students in the classroom and repositioned into an imagined moment-by-moment and highly-focused process of micro-planning the content of the simulation.

**Table 3. Summary of the interactions between dependency-centered design (left) and teacher agency (top), in Jerry's case**

| | Projection (Future-Oriented) | Iteration (Past-Oriented) | Practical-Evaluative (Action-Oriented) |
|---|---|---|---|
| **Pedagogical Principles** | √ | | |
| **Exemplars** | | √ | |
| **Dependency Features** | | | √ |

The relationship between dependency-centered design and teacher agency that this case suggests is thus summarized in Table 3 above. First, he designed his simulation using the pedagogical principles of virtual internships and activated the projective (future-oriented) dimension of agency. Second, he used the content of an existing virtual internship as an exemplar and activated the iterative (past-oriented) dimension of his agency. Finally, he used the coordinated representations in VIA to manage the dependencies of his content and activate the practical-evaluative (action-oriented) dimension of his agency.

While this is of course only one example of pedagogical authoring, we argue that it nonetheless illustrates how the interactions between authoring and agency unfold in the creation of an immersive simulation, and suggests important similarities and differences between how teacher agency unfolds in immersive simulations and more traditional classrooms.

With more traditional classroom content, the management of dependencies and activation of the practical-evaluative (action-oriented) dimension happens during both the authoring of the content and use of the content in teaching situations. After authoring a lesson plan, for example, teachers may have to modify and adapt that plan in response to the emerging conditions of their classroom. However, immersive pedagogical simulations are not as malleable as more traditional lesson plans. Their narrative and technological complexity make it difficult or impossible for teachers to make changes to them quickly, let alone on the fly. And as Jerry's case shows, this complexity may also mean that teachers will not be able to rely on their prior experience as they work with and author these simulations. These two difficulties might result in a paradox: pedagogical simulations are powerful educational tools, yet their complexity can stifle teachers' agency.

Jerry's case suggests one way out of the paradox. In order to maintain his agency while working with immersive learning environments like virtual internships, Jerry had to shift focus from the enactment phase of pedagogy to the planning phase of pedagogy. And in order to make this shift, Jerry envisioned goals for his students in relation to the pedagogical principles of virtual internships, he used the exemplar embedded within VIA to make up for his limited prior experience, and he used the dependency features of the tool to make decisions about what student's would experience and how the simulation would respond during future teaching situations. Thus, participating in the pedagogical authoring of this simulation was necessary for him to retain his agency as a teacher while using this immersive environment.

The results of this study have several limitations. Most obviously, the example of pedagogical authoring we have described is limited to one educator and one type of pedagogical simulation, virtual internships. However, the features that virtual internships share with pedagogical simulations in general, and the extent to which Jerry's experiences are representative of educators who engage with pedagogical simulations, suggest that our results have import beyond the specific context discussed here. But more importantly, these results warrant further study of the pedagogical authoring process and suggest specific features of the process to investigate with more data in hand. In future work, we plan to collect data on multiple users of our authoring tool, including interview and clickstream data, which will allow us to quantitatively support our findings and compare user experiences.

Another limitation is that our evaluation of the pedagogical authoring process does not take student experiences or outcomes into account. We plan to investigate student experiences with authored pedagogical simulations and the impact these environments have on student learning to see the effects of pedagogical authoring more completely.

Finally, we acknowledge that teachers have always used their prior experience, their objectives and ideas about how students learn, different pedagogical principles, and other exemplar materials when planning teaching. But our results suggest that when teachers use immersive environments in particular, there is a shift in teacher agency towards the preparatory phase of teachers' work, and that this shift has important implications for the design of pedagogical software and pedagogical authoring tools.

In particular, this example suggests that focusing on pedagogical dependencies is a critical feature of the design of pedagogical software and authoring tools. Moreover, this focus on dependencies should be informed not only by students' need to experience a coherent environment after teachers' modification, but also by teachers' equally important need to maintain a practical and evaluative engagement with the teaching situation.

## CONCLUSION

The case we have presented suggests that the components of dependency-centered design align with the dimensions of teacher agency. And in turn, this alignment suggests that teacher participation in the authoring of pedagogical simulations, mediated by proper tools, can support teacher agency. While more examples of this kind of pedagogical authoring are needed to test the generalizability of these claims, our results suggest an explanation of how the paradox of pedagogical simulations arises and certain recommendations for resolving it.

First, using a pedagogical simulation without articulating pedagogical principles, or designing student activities without those principles in mind, can leave teachers without a clear sense of direction. Thus, authors of pedagogical simulations should have particular pedagogical principles in mind and these principles should be enacted in the activities that students participate in during the simulation.

Second, the absence of clear and relevant exemplars can leave teachers without the ability to build on prior experience, especially when they choose to teach with pedagogical

simulations that are new to them. Such situations can further detach the teacher from being able to act towards his or her students. Thus, teachers who use pedagogical simulations need exemplars that can make up for their limited prior experience and provide models for their curriculum.

Finally, the inability to access, review, and modify the dependent actions and responses of the simulation can hinder teachers' agency and leave them without the ability to guide their students. Thus, we need tools that help teachers manage the dependencies within pedagogical simulations so they can effectively make decisions related to the student experience.

We thus argue that dependency-centered design maintains teacher agency in two important ways. First, it shifts our thinking about teacher work to increase the focus on preparation and the relation between preparation and in class work. We need to regard the preparation and "at the desk" modifications that teachers make to classroom materials as a form of practical-evaluative or action-oriented thinking in order to understand the role of the teacher in the technological classroom. Otherwise, we will end up studying only a fraction of the actual agency that teachers enact.

Second, we need to shift our attention from *creating* meaningful and rich simulations for students towards developing tools that allow for *recreating* those experiences by teachers in a way that maintains the coherence and immersive power of the simulation, but also maintains teacher agency in adapting the simulations for the needs of their students.

Dependency-centered design, then, is an approach to the development of immersive simulations that focuses on modifiability and coherence as a means to integrate immersive technological experiences in a way that avoids teachers' detachment from the ongoing dialogic relationship with their students.

Obviously, drawing firm conclusions about the relationship between the preparation and enactment of curricula changes when teachers use immersive simulations requires further data collection. We need more information describing the preparation phase and actual enactment of curricula by teachers, including both teachers working with immersive simulations and those working with traditional materials. However, the preliminary data we present here suggest that because highly interactive, immersive and complex learning environments make it difficult for teachers to make decisions on the fly, dependency-centered design is a way to maintain teacher agency when teachers use immersive simulations in the classroom.

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