Design in Game-Based Learning

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Abstract: Educational games have shown promise as a technology that can improve learning, and education, but research has yet to produce games that can consistently and sustainably fulfill this promise. One reason to the shortcomings of research may be that game based approaches, including design approaches, have thus far focused on developing domain-based theories and methods of research and design and have tended to neglect design frameworks. In this paper, we identify design as an area that will be necessary to study in order to develop effective educational games and suggest that literature begins by presenting failure in design in order to identify what needs to be improved.

Keywords: educational games, learning, design research, design frameworks

Introduction

The last decade's interest in using games to help transform education for the 21st century has produced mixed results. The results are mixed in that, while games have been repeatedly shown to have the potential to contribute positively to learning and education, we still don't know how to consistently design games that are regularly used, that improve learning in predictable and desirable ways, and that require a reasonable and attainable amount of resources especially when sustained at scale. That is, similar to educational technology predecessors (e.g. LOGO), one of the major challenges that educational games faces is not whether they can produce good learning, but how learning games can be developed, distributed, used, and supported given present contexts. These challenges are not insurmountable, however they require addressing a major gap within design research literature centered on theories of design.

Design is generally acknowledged as essential for the development of education technology interventions that can effect authentic, local, and possibly large-scale change, as well as for conducting rigorous studies in messy environments (DBRC, 2003; Fishman, Penuel, Hegedus, & Roschelle, 2011; Penuel, Fishman, Cheng, & Sabelli, 2011). Despite its importance, design itself has been relatively under-theorized or at the very least, infrequently discussed in CSCL literature (though see Kirschner, Strijbos, Kreijns, & Beers, 2004). This is especially true in the burgeoning field of games research where the focus has been to test whether games can be useful for learning, rather than how games can be developed to provide long-term improvements (Clark, Tanner-Smith, & Killingsworth, 2014). For example, in describing the development of Quest Atlantis, a virtual world where student players can engage in pro-social and scientific narratives, Barab et al. (2004) use components of ethnography, design-based research, and action research to describe the conditions and processes that contributed to their design. As participant observers, they talk about how their designed technology was intended to "aid children in valuing their communities and in recognizing that they have important ways to contribute to their communities and the world" (pp 255). Conducting a "critical design ethnography" Barab et al. (2004) present a sense of why they created the program that they did, however the readers are left with little understanding of the relationship between how particular elements of their design came about (e.g. why was it digital, multiplayer, quest-based), how these elements evolved throughout the project and why certain designs were favored or emerged. As an even more specific example, consider that the authors reported that the game can be customized in order to fit local content and that it already contained over 400 stock quests that the teachers and players could choose from. The author's description leaves readers guessing with regards to how they ended up with this configuration of quests as a solution to improve flexibility or whether more quests or more robust versions of the current ones might offer better alternatives. The critical design ethnography they employed was useful in conveying a sense that the project required balancing multiple agendas and that the technology had to be flexible in its design, especially when moving across different contexts of play. However, the ethnography does not convey how the authors determined what they needed to do to the technology to make it flexible in the first place or a theory of design that would describe how to improve it in future versions.

The purpose of this paper is to spur discussion about design, particularly the design of educational games and their associated learning environments. Because game-based educational technologies continue to

gain popularity in formal and informal educational environments, theories and guidelines regarding the parameters of future designs are increasingly necessary, both to improve research and understanding of how games affect learning, but also to improve the designs themselves. In particular, what's needed are "design frameworks" (Edelson, 2002), which can be produced through design studies and present "a generalized design solution" to address the problems identified by a prior research whilst using design methods to get there. While design research has regularly focused on the development of domain theories and improving design methods, design frameworks, including how design solutions are generated, remain under-developed or at the very least, not well-shared within games literature.

In the remainder of this paper, I present a brief overview of three design research approaches in which design is considered essential in order to characterize its current role. I then present three frameworks that can be useful when thinking through and sharing game-based designs. Neither this review nor the frameworks presented are exhaustive, but are meant to serve as a point for discussion on how to directly address designs and practices associated with game-based education, putting them on equal footing with the learning goals they currently serve.

Three examples of design in research

To contextualize the issue of design in game-based learning, consider three popular approaches to educational technology research in which design plays a central role: design-based research (DBR), design-based implementation research (DBIR), and Instructional Design (ID). Generally, all three approaches address the challenge of creating practical educational interventions that are effective in authentic learning settings (e.g. classrooms) and that simultaneously produce rigorous research.

Design-based research incorporates work from both Brown (1992) & Collins (1992), fully embracing the messiness of authentic settings and the valuable feedback that the classroom contexts can generate. Rather than attempting to isolate variables for later laboratory testing, however, DBR tends to use a process of iterative, theory-informed design to generate claims that can be applied to other contexts, to better understand the context of the intervention's enactment, and to produce demonstrable learning gains at the site of the intervention (Barab & Squire, 2004). Over the past decade, design based research has begun to find stronger footholds internationally, and has developed from a philosophical stance into a productive research approach.

Similar to design-based research is design-based implementation research (DBIR) (Penuel et al., 2011). DBIR has four key elements:

- A focus on persistent problems of practice from multiple stakeholders' perspectives
- A commitment to iterative, collaborative design,
- A concern with developing theory related to both classroom learning and implementation through systematic inquiry
- A concern with developing capacity for sustaining change in systems (p. 332, Penuel et al., 2011).

DBIR, similar to DBR, uses design to augment research practices in order to advance theory and to achieve effective, practical interventions. A key distinction between the two comes from DBIR's extension of "what works" to "when, how, and for whom?" (p. 335, Penuel et al. 2011), and its focus on integrating effective interventions into on-going practices, settings and cultures in order to achieve long-last systemic change.

Finally, instructional design has, since the late 1980s, drawn explicit attention to the intersection of educational practice and theory, teachers and researchers, though an orientation toward design. Reigeluth (Reigeluth, 1999) describes ID as composed of *situations* under which designs can and cannot be applied and the *methods* by which designs can be implemented. To describe the situations, Reigeluth proposes identifying the conditions of instruction (e.g. who is the learner) and the desired learning outcomes (e.g. how effective is it). Methods include how to perform the intervention (e.g. pedagogy), as well as the parameters of the artifact itself (e.g. it should be realistic). Together, the components of ID provide the designed methods of instruction and the conditions under which they should be applied.

Design as peripheral versus design as a focus

The goals of DBR, DBIR, and ID include gathering evidence for learning, defining theories that relate the designs to the learning outcomes, prescribing how designs should be used, and for DBIR in particular, how the intervention can effect systemic change. These approaches can be seen as responses to Collins' (1992) call to apply design science to education. At the time, Collins argued, education technology research and development faced major shortcomings, including a tendency to use technology developments that were atheoretical and to

over-emphasize the potentially biased examination of whether these technologies could produce significant gains in learning. At the same time as Collins' work, Brown (1992) identified what she saw as major challenges to current educational research approaches, emphasizing the tension between complex, spontaneous, and difficult to control classroom learning with laboratory-centric investigations, where isolating variables is taken for granted. For Brown, research that moves between the classroom and the laboratory provides the best of both worlds, allowing for the identification of learning variables in situ, coupling testing in tightly controlled settings with a study of their effects in authentic, real-world contexts.

Despite the way that design is a common factor amongst the reviewed research approaches, it has not in and of itself, been the focus. Instead, the approaches are "design-oriented" (p 12, Reigeluth, 1999) or use design "as an approach" (p 331 Penuel et al. 2011) in order to achieve their other outcomes. This reflects a view of design as a means for theory testing (Cobb et al., 2001), where a researcher takes previously developed theories or hypotheses and instantiates them as a design in order to test them. Design, generally, is a means to an end. In some cases the end is an improved understanding of the strengths and limitations of the *theory* or *hypothesis* in question while in others it's some resolution of a local, meaningful issue (e.g. Penuel et al. 2011). Regardless, design is *used* in design research, not the purpose of it. Being a means to an end does not exempt design from critical examination or theorization.

Approaches that treat designs as instantiations of (and pursuant to) particular theories are problematic for two reasons. First, they treat design as overly rational, instead of considering what's designed is an imperfect instantiation of a theory at best and a lethal mutation at worst. Designs are the products of their contexts, or accumulations of real-world development processes including hundreds of decisions about procedure, the problem that is being solved, and the way the solution is addressed through the design (Edelson, 2002). In other words, design does only address the configuration of the artifact, but is the process that produces it. As an alternative to the rational approach, Schon (1984) describes this process as *reflection-in-action*, in which designers draw connections between the immediate design problem and their own prior experiences, relying on repertoires of design they have built up through professional practice or experiences. By drawing connections between prior work and the problem at hand, designers frame the problem so that it is familiar and understandable. And while the designer seeks similarities between the current design and prior work in order to propose solutions, the conditions of the world "talk back" to the designer, triggering a re-framing of the problem based on evolving constraints that the design must meet, including differences between the current and prior situations. When a problem is well-defined, generating design solutions means meeting the initial constraints of the project, but when working in an ill-defined problem space, the designer must actively identify the similarities and differences between the current design and prior work in order to evaluate potential solutions' relevance or applicability.

Schon's definition of design as a relational and active process is not the authoritative definition of design, but is useful in highlighting what's missing from current approaches. In particular, designs are often conveyed in terms of principles or heuristics that are overly focused on intent or method. For example, Edelson cites van der akker's (1999) use of heuristics to convey design principles in the form:

> "If you want to design intervention X [for the purpose/function Y in context Z], then you are best advised to give that intervention the characteristics A, B, and C [substantive emphasis], and to do that via procedures K, L, and M [procedural emphasis], because of arguments P, Q, and R." (p. 9, van der akker, 1999)

While heuristics such as these can clearly capture the general character of the design, the logic of the designers, and their recommendations for recreating desired outcomes, they rest on the assumption that design is a direct translation from intent to artefact. Because a reflection-in-action approach considers contingency as a core characteristic of the design process, it suggests a need to develop new ways to communicate design especially conveying how the environment "talks back" to the design. Instead of expressing the characteristics that might be desirable within an artifact and explaining how to directly and logically instantiate them, a design framework might instead try to express the relationship between the artifact and the context as they evolve over time.

Second, placing theory above design rather than alongside it runs counter to recent calls to action in education research (e.g. Bang, Cobb, Jackson, Sorum, & Gutiérrez, 2014; Lave & Hall, 2014). Developing effective educational interventions requires moving beyond measures of treatment effect to the coordination of design and practice amongst researchers and practitioners. Though theory is essential, positive systemic change requires directly addressing the interface between theory and the contexts in which a theory is applied, or in other words directly addressing design.

What to share, how to share it?

As game-based learning evolves from a field that investigates *whether* games are good for learning to *how* games can be good for learning, what's needed is a better understanding of how and why the designed components of the educational game came about, especially with regards to the intended and unintended components as well as the conditions of development and use. Design-research approaches are perhaps the current best approach for tackling this problem and warrant what Anderson & Shattuck (2012) describe as a "cautious optimism" in their ability to generate testable theories and practical designs that can be used to improve learning using methods such as iterative development and user testing. As a method, design based research is useful, particularly for its role in theory generation and testing, but there is also a growing need to improve the community's knowledge about how to design good educational games, the varying qualities of these designs, the processes involved in making them, and their use in context.

What's missing in games research, as well as in education technology design generally I argue, is a focus on conveying and improving the theories that explain how we conceptualize design and the practices associated with how we carry it out. What's needed are new ways of sharing design so that other researchers or education practitioners can adapt the design to other conditions and in so doing, improve our understanding of which components are locally contingent and which are generally applicable (Hoadley, 2002). Current approaches that produce "design principles" or recommend including affordance X in game Y to elicit learning gain Z are insufficient for conveying the messy practices and processes that are inherent to design. Theories of design like reflection-in-action provide some advancement in these regards, and suggest ways to frame what should be done, theorized, and shared when conducting design research that incorporate the relational aspect of design. There are of course, other approaches to developing and sharing frameworks that enable the systematic testing and replication of game designs and the following section outlines one alternative, the social infrastructure framework.

Educational games that are not accompanied by an associated theory of learning and design may generate findings that are difficult to replicate, generalize, or otherwise apply to other contexts. At the same time, games that address learning without regard for design, including how the game meets pre-defined and newly developed constraints, run the risk of games that aren't used and interventions that aren't used can't improve learning, no matter how large their effect size. Though video games, generally, are impacting many players' lives and may hold potential for improving learning, more work is needed especially in advancing our understanding of how good designs are produced in order to develop educational games that are not only effective, but used daily and widely.

Such a format for sharing educational game design has been absent thus far, especially as compared to the other products of design research, domain theories and design methods. *Domain theories*, typically academic in nature, fall under models of philosophy of science, taking the form for example, of a hypothesis to be tested (group A performs better than group B) or stemming from conjectures about the nature of a thing (e.g. group A is related to group B in some way). These hypotheses or conjectures, in turn, can be further interpreted with respect to some disciplinary paradigm, in which an entire domain may generally adopt some key assumptions/perspectives (Kuhn, 1962). *Design methods*, are similarly well-established, often described in published definitions of design research. For example, Collins, Joseph, & Bielaczyc (2004) describe a process of progressive refinement, in which designs are put into real-world contexts in order to see how they work and to generate feedback in order to perform iterative design. Brown's design experiments have as a hallmark, a process or method for moving between authentic classroom settings and controlled laboratory environments in order to ensure the effectiveness of the intervention and isolate key variables. *Design frameworks*, unlike domain theories and design methods, have not yet been, at least in educational game research, extensively discussed or clearly detailed and thus far prior work has not been particularly useful in presenting designs.

Though the role of design and its relationship to learning may vary depending on the aims of the research, what remains consistent across research design perspectives is the commitment to basing designs on feedback from real-world contexts in order to generate theory that can be applied to future designs and their use in context. Even approaches that use design as a means for theory testing take into consideration the importance of the interaction between the design and its use in context. Despite its importance, design knowledge is difficult to share, and has tended to either convey abstract principles that are difficult to put into use, or concrete decisions that are context-dependent and difficult to generalize. This is due in part because of the way that design includes both deliberate decision processes and the confluence of contextual factors in which the design process unfolded. Design includes considerations of the tool itself as well as its adaptation to local constraints, not all of which are immediately apparent. Improving design means conveying and improving upon how we share and address both of these design components, regardless of the role of design in research, as a learning intervention's success depends on its design. While determining whether learning has occurred over the course

of a game-based intervention is important, understanding why or how particular designs effect learning and how designs can be recreated in other contexts remains necessary for the field to test and advance theory and to create interventions that can be supported and scaled.

A framework for design: Social infrastructure

Bielaczyc (2006) outlines four dimensions of classroom structures that can be designed: the cultural beliefs dimension, the practices dimension, the socio-techno-spatial relations dimension, and the interaction with the "outside world" dimension. The beliefs dimension includes the way that teachers and students think about learning and knowing, their identities, and the purpose of the tools or technology being used. The practices dimension includes students' and teachers' activities including both what they do with the tool and without it, as well as the social structures of the participants. The socio-techno-spatial relations dimension refers to relationship between the physical and cyberspace as well as the configurations of the students, teachers, and tools within. Finally the interaction dimension considers the way that knowledge is brought into the activity, produced by the activity and consumed by others, and the way that students interact with others.

These dimensions help characterize the aspects of classroom learning that are amenable to design and identify the variables that are important for effectively integrating learning technologies. For example, to show its usefulness, Bielaczyc (2006) analyzes an already-completed study using the social infrastructure framework to identify the participant structures that were described but not previously connected to the way that they contributed to the successful design of a digital collaborative learning activity.

The social infrastructure framework contributes significantly to design research by identifying dimensions that should be critically examined when designing interventions and assessing learning outcomes. Additionally, the dimensions of the social infrastructure framework can also be combined with *implementation paths* or descriptions of the trajectories that teachers go through when adopting new learning technologies, providing a more complete view of a new tool's use. The framework's dimensions however, do not address the dynamic relationship between the dimensions and the design, including its character and what can be done to change it. It is a useful tool presuming the researcher knows how to design well already.

Design as narrative

Similar to the notion of implementation paths is Hoadley's (2002) *design narrative*. Design narratives are characterized by their presentation of a plot that describes and relates the important development events as they unfold over time in a particular setting. Still, for narratives, the challenge is in identifying the components of design that are important enough to convey, as generating design based research results that are credible is a core issue of DBR generally (Barab & Squire, 2005). Narratives, though they address the need to provide details about the contingency associated with the design process, are inadequate on their own in reflecting back on the process itself – once complete, how does one improve or expand upon the design that was just developed and how do we get better at reflecting-in-action?

Where things went wrong

Though educational video games have been around for as long as their non-educational counterparts, they have yet to see the same rates of adoption or impact. This is, in part, due to the way that research has focused on establishing evidence that games produce learning, for example by 1) measuring learning gains produced through game play, 2) comparing game and non-game conditions, or 3) studying examples game-based learning in authentic gaming environments and linking the results of these studies back to the games' design. This research agenda is important in that it provides the political will for supporting the use of games for learning. At the same time, the focus on learning has made it difficult to advance design theory or the outcomes of design. To address these shortcomings, it may be useful to begin considering how we might better communicate projects, both in terms of their learning outcomes, but also in terms of their failures.

That is, design can be considered a process of "proactive failure analysis," in which identifying how a design *fails* (or is perceived to fail) is the first step for improving it. Not reporting failures inhibits design improvements by preventing others from understanding what needs to be "fixed." Additionally, characteristics of design will inevitably differ across projects or fields, and the qualities that lead to success in one classroom may be exactly the same qualities that cause failure in another. Exposing failure, connecting it to design, and explaining context will contribute to the development of design frameworks by providing the opportunity for other designers to understand what happened and to propose alternative solutions.

Finally, considering we as researchers are not the only parties invested in educational design projects, and describing what we consider to be failures may be overly narrow if it discounts other stakeholders in the project. As Petroski (2008) writes "Maker and user, let alone middle man, can have different expectations of

what constitutes acceptable performance (p. 106)" Addressing failure means addressing what all of the participating parties deem as areas of design improvement, as successful research design may not necessarily result in successful teaching design. If we expect the technologies that we create will be used and valued by students and teachers alike, considering failure may help to democratize the design process by including the voices of other project stakeholders.

To game design and beyond

Games are not designed equally, and advancing "good" design is important (Gee, 2003). Game-based learning research has tended to leave readers guessing about how or why particular designs came about, however, making it difficult to establish what good design is or how to do it. It's possible that this neglect may be easily rectified, as there are many theories and approaches to design that may be applicable to educational games. For example, the field of instructional design has a long history of attending to the design of educational technology and educational environments more generally (Gagne, 1981), and organizational management has theorized the role of technology as mediator within an organization (Orlikowski, Yates, Okamura, & Fujimoto, 1995). Finding common ground with educational games, fields who theorize design and applying contemporary, relational theories of learning, will likely be productive. Regardless of which fields' cross-pollination produces fruit, addressing the literature gap in the design of educational games is the first step in designing for lasting positive systemic impact. This paper specifies further steps for community action, calling for a discussion of how we may better communicate and clarify relevant 1) design theories and definitions, 2) design success and who gets to define what counts as success and 3) design failures, including what went wrong and why.

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