Towards an open, collaborative repository for online learning system design patterns

Design patterns are high quality solutions to known problems in a specific context that guide design decisions. Typically, design patterns are mined and evaluated through four methods: expert knowledge, artifact analysis, social observations, and workshops. For example, experts discuss: knowledge, interpretations of artifacts, social patterns, and clarity of patterns. In this paper, we introduce a fifth method, a data-driven design pattern production (3D2P) method to produce design patterns and conduct randomized controlled trials as a means to evaluate applied design patterns. We illustrate the 3D2P method in the context of online learning systems (OLSs) that are difficult to create, update and maintain. To overcome such challenges, we propose an open repository for OLS design patterns, evaluation data, and implementation examples. On the repository, researchers can collaborate in the six stages of the pattern lifecycle (i.e., prospecting, mining, writing, evaluation, application, applied evaluation). The repository provides five benefits: researchers from different backgrounds can (a) collaborate on design pattern production; (b) perform distributed tasks in parallel; (c) share results for mutual benefit; (d) test patterns across varied systems and domains to explore pattern generalizability and robustness; and (e) promote design patterns to elevate OLS quality.

1. Introduction

Increasingly, online learning systems are gaining popularity. Allen and Seaman (2008) report that over 3.9 million students took at least one online course. Coursera, a massive open online course (MOOC), had over 12 million users taking 1,027 courses in May, 2015 (Coursera, n.d.). The Cognitive Tutor online tutoring system reported over 250 million student observations per year (Sarkis, 2004; Carnegie Learning, n.d.) and the ASSISTments math online learning system reported close to 50,000 students from 48 states in the United States using the system each year (Heffernan & Heffernan, 2014; Mendicino, Razzqa & Heffernan, 2009a; ASSISTments, n.d.).

Despite increasing popularity, online learning systems have shortcomings. For example, massive open online course (MOOC) usage statistics show low student engagement, low course completion rates, and high dropout rates (Jordan, 2014; Yang, Sinha, Adamson & Rose, 2013). Students experience emotions that hurt learning (e.g., frustration, boredom) and they sometimes “game the system” by exploiting help and system feedback to find the answer instead of learning. Three possible explanations for such maladaptive student behaviour includes: confusing learning system interfaces, poor design of subject content, and individual student traits such as, background knowledge, learning goals, motivation (Craig, Graesser,
Some online learning systems that addressed such interface, content, and student challenges significantly improved student-learning outcomes. However, the same developers had difficulty replicating their prior successes. For instance, many studies showed the effectiveness of Cognitive Tutor Algebra (Koedinger, Anderson, Hadley & Mark, 1997; Morgan & Ritter, 2002; Sarkis, 2004; Mendicino, Razzaq & Heffernan, 2009b), but the effectiveness of Cognitive Tutor Geometry, which was largely developed by the same team, was not as successful (Pane, McCaffrey, Slaughter, Steele & Ikemoto, 2010). Researchers tried formalizing lessons learned from existing design projects and studies using design principles, but encountered conflicts between design principles and had problems applying them in different contexts (cf. Mayer & Moreno (2002), Pashler et al. (2007), Kali (2008)). Differing results from designs based on design principles and guidelines are attributed to the interpretation of design guidelines and principles into specific domains (Jones, 1992).

Design patterns are high quality solutions to known problems in specific contexts (Alexander, 1979). Design patterns can be used to overcome the limitations of design principles in various domains making it a good alternative (Mahemoff & Johnston, 1998; Van Welie, Van der Veer & Eliëns, 2001; Borchers, 2001; Chung et al., 2004; Kunert, 2009). Although design patterns can guide design decisions in online learning systems, they are relatively new and the currently available patterns mostly focus on pedagogy; notable exceptions include patterns for learning management systems (Ageriou, Papasalourous, Retalis & Skordalakis, 2003), person-centered e-learning management systems (Motschnig-Pitrik & Derntl, 2003), and MOOCs (MOOC Design Patterns, 2015). For instance, there are design patterns on content presentation, methods for feedback, learning activities, and assessment (Frizell & Hübscher, 2011; Derntl, 2004; Anacleto, Neto, & de Almeida Neris, 2009), but not much for OLS user interfaces, content and presentation of problems in online exercises, or automated student feedback for online exercises.

Some very popular online learning systems in the United States such as Cognitive Tutor (Ritter, 2011) and ASSISTments (Heffernan & Heffernan, 2014) were developed without design patterns, but collected over a decade of data describing students’ interactions with the system. Researchers developed a methodology called 3D2P (Data-Driven Design Pattern Production) that uses data collected from existing online learning systems to: inform the design pattern production processes, focus stakeholders on important design decisions, evaluate the quality of design patterns, and collaborate with other stakeholders to refine design patterns (Inventado & Scupelli, in press).

The methodology is run incrementally to ensure an online learning system’s quality as it evolves over time. Its first three steps (i.e., pattern prospecting, mining, writing and evaluation) use existing data collected from the system, while the last step (i.e., evaluation) requires conducting randomized controlled trials (RCTs) to verify the quality of patterns in implemented systems. One limitation of the methodology is that it may be difficult to conduct some RCTs to test and verify design patterns that require significant system modifications to test. Consequently, while some RCTs are difficult to conduct on a particular online learning system, other researchers could test the patterns in question with their own system and evaluate through RCTs. Analysis about a pattern’s effectiveness in a different system helps to verify the pattern’s quality and may provide insights to refine ineffective patterns.

Collaborating to evaluate design patterns provides many benefits to multiple communities ranging from design pattern authors, online learning system designers, students, and educators. Researchers can also contribute to design pattern production in four ways: (a) through data analysis (i.e., hypotheses from data can lead to the definition of new patterns); (b) pattern writing (i.e., patterns can be adapted and evaluated); (c) pattern application (i.e., variety of contexts for applying patterns describe its generalizability and robustness); and (d) pattern application evaluation (i.e., uncovered pattern definition issues can inform pattern refinement).

Collaboration between researchers to produce design patterns has five advantages. First, it can speed up the process of pattern prospecting, mining, writing, evaluation, application and application evaluation because it allows parallel work. Second, researchers from different backgrounds can contribute their particular expertise to design pattern production expanding the overall quality of pattern writing, data analysis, and evaluation. Third, pattern analyses, evaluations, and refinements are available in one central location. Fourth, a pattern’s robustness and generalizability can be evaluated as different researchers apply the pattern in different contexts (e.g., different
In-depth

The following sections of the paper present a review of related literature, the ASSISTments math online learning system, the data-driven design pattern production (3D2P) methodology and its application on ASSISTments data, a collaborative framework for producing online learning system patterns, and the current state of a pattern repository being conceptualized for supporting the collaborative framework.

2. Literature Review: Design patterns and data-driven approaches

Design patterns provide quality solutions for known problems situated in a particular context (Alexander, 1979). Applying design patterns to projects can result in lesser implementation issues and future complications. Design patterns have also been used to share successful solutions between designers (Gamma, Helm, Johnson & Vlissides, 2005), and as a medium for communication and collaboration between designers and users (Borchers, 2001; Erickson, 2000).

Some examples of patterns for online learning systems include a pattern language for learning management systems (Avgeriou et al., 2003), a pattern language for person-centered e-learning (Motschnig-Pitrik & Dernstl, 2003), a pattern language for adaptive web-based educational systems (Avgeriou, Vogiatzis, Tzanavari & Retalis, 2004), and MOOCs design patterns (MOOC Design Patterns, 2015). Some design patterns that were not specifically designed for online learning systems, but address similar problems and contexts can also be adapted. For example, there are design patterns for learning (Iba, Miyake, Naruse & Yotsumoto, 2009; Köppe, 2012; de Cortie, van Broeckhuijzen, Bosma & Köppe, 2013), pedagogy (Eckstein, Manns, Sharp & Sipos, 2003; Sharp, Manns & Eckstein, 2003; Bergin et al., 2004; Kohls, 2009; Köppe & Schalken-Pinkster, 2013), and assessment (Mislevy et al., 2003; Gibert-Darras et al., 2005; Delozanne, Le Calvez, Merceron & Labat, 2007; Wei, Mislevy & Kanal, 2008).

There are four methods commonly used for identifying or mining patterns namely: introspective approach, social approach, artifactual approach, or pattern-mining workshops (Kerth & Cunningham, 1997; DeLano, 1998; Kohls, 2013). Pattern mining is often implicitly followed by pattern writing, which gives form to the design pattern. In the introspective approach, pattern authors use their own experiences to identify patterns. In the social approach, pattern authors use their observations of the environment or draw experiences from other experts to identify patterns. In the artifactual approach, pattern authors compare and contrast existing artifacts (e.g., successful projects, effective solutions) to uncover underlying patterns. Finally, in pattern-mining workshops, pattern authors analyse the experiences of different experts in focus group discussions to uncover design patterns. Unlike the social approach, pattern authors can easily communicate and collaborate with experts in pattern-mining workshops so they can get more ideas and feedback faster.

Patterns are usually evaluated through peer review in focus groups or pattern writing workshops to assess their quality and refine patterns when needed (Chung et al., 2004). However, the application and usage of patterns are also being evaluated. For example, Borchers (2002) reported the effectiveness of using design patterns for teaching Human Computer Interaction (HCI). Dearden, Finlay, Allgar, and McManus (2002) reported that design patterns empowered users to communicate and collaborate with designers, and to develop complete designs in a participatory design setting. Chung et al. (2004) conducted an empirical study on using a pattern language in a simulated design activity with experienced designers, which showed that the pattern language helped designers understand unfamiliar domains, communicate ideas, avoid design problems, and accomplish tasks more quickly. Riaz, Breaux and Williams (2015) presented a survey on commonly used measures for evaluating software design pattern applications, which included efficiency,
quality, correctness, completeness, complexity, usability, communication, creativity, modularity, and size.

Evaluation is fundamental for online learning systems because it guides the feedback that helps students learn. The goal of helping students learn is shared by design patterns for online learning systems and educational design patterns. Therefore, in the learning domain, design patterns are evaluated in two ways: first, as design patterns, and second, how well the design patterns improve student learning. In short, the design patterns for online learning systems need to improve the end goal of improving student learning outcomes. Limited evaluation of patterns for online learning systems without validation of the patterns in use may explain why some design solutions succeed in some contexts but fail in different contexts (e.g., different subject content, presentation medium – desktop vs. mobile, student background knowledge, student motivation).

Educational data mining and learning analytics provides teachers, researchers, and other stakeholders with methodologies and tools to better understand how design decisions affect student learning and performance (Baker & Inventado, 2014; Mor, Ferguson & Wasson, 2015; Persico & Pozzi, 2014). Insights from student data analysis can help to: identify student needs, develop better pedagogies, and implement better learning systems (i.e., improvements in system design and feedback). For example, educational data mining and learning analytics were commonly used for three main reasons to: (a) identify student behaviours that hurt learning (e.g., Craig et al. (2004), Baker et al. (2008), Baker et al. (2010), Hawkins et al. (2013); (b) help teachers gain insights about student behaviour, performance, and assess possible interventions (e.g., Arnold and Pistilli (2012), Dietz-Uhler and Hurn (2013), Heffernan & Heffernan (2014), Haya, Daems, Malzahn, Castellanos and Hoppe (2015); and (c) to improve system design and feedback (e.g., Cho, Gay, Davidson and Ingraffea (2007), Kim, Weitz, Heffernan and Krach (2009), Robison, McQuiggan and Lester (2009), Heffernan & Heffernan (2014).

Ensuring the production of high quality patterns is challenging for four reasons: first, it is expensive (e.g., face-to-face meetings in international conferences); second, it lacks incentive for evaluating, critiquing, improving, and evolving existing pattern languages; third, author attribution is an issue; and fourth, stakeholders, especially designers and end-users who are the primary beneficiaries of patterns, are often not part of the process (Dearden & Finlay, 2006). There have been calls for a widespread collaboration between stakeholders in the production of design patterns (Bayle et al., 1998; Dearden & Finlay, 2006). Producing online learning system patterns can benefit significantly from collaboration. Much work is needed for a domain that evolves rapidly over time as new content is added, new functionalities are implemented, new technologies are supported, and new stakeholders get involved in its development. The Pattern Language for Living Communication Project is a good example of a broad collaborative effort for proposing, critiquing, and editing patterns online, which currently hosts 3 pattern languages about the public sphere and contains over 240 patterns designed by more than 120 authors from approximately 20 countries (Schuler, 2002; Schuler, 2004; Public Sphere Project, n.d.).

3. ASSISTments

ASSISTments is a learning platform that allows teachers to create exercises with associated questions, hints, solutions, videos, and the like, that can be assigned to their students. It gives teachers immediate feedback about their students’ performance (Heffernan & Heffernan, 2014). ASSISTments puts teachers in charge of the learning process by helping uncover confusing topics that require further in-class discussions, gauging how prepared students are for lessons, and identifying students who need support and the type of support the student needs.

ASSISTments was built using architecture and interface development best practices with the help of expert advice and content (i.e., problems, answers, hints, feedback) from math teachers. Over time, more content was added into ASSISTments from math textbook questions and teacher-contributed variations of existing questions in ASSISTments (Heffernan & Heffernan, 2014). New features were also added into ASSISTments such as adding grading flexibility for teachers and giving parents access to their children’s grades (Heffernan & Heffernan, 2014). Researchers were granted access to student data and allowed to run randomized controlled trials that varied content, system feedback and others (e.g., Broderick, O’Connor, Mulcahy, Heffernan and Heffernan (2012), Li, Xiong and Beck (2013), Whorton (2013).
ASSISTments has been collecting data since 2003 from close to 50,000 students each year in 48 states of the United States (Heffernan & Heffernan, 2014; Mendicino et al., 2009b; ASSISTments, n.d.). Student learning experience is represented in the data using multiple features such as the number of hint requests, the number of attempts to solve a problem, answer correctness, action timestamps and affect predictions (i.e., concentration, frustration, confusion, boredom) (Heffernan & Heffernan, 2014; Ocumpaugh et al., 2014). Student affect was predicted by a machine-learning model built using previously collected expert-labelled data of students using ASSISTments.

Some features used for prediction include the number of incorrect answers, time duration for answering a problem, and hint requests (Baker et al., 2012; Ocumpaugh, Baker, Gowda, Heffernan & Heffernan, 2014).

4. Data-driven design pattern production (3D2P)

ASSISTments was used to test the methodology because it has a large data set available (i.e., 6,123,424 instances using data between September, 2012 to September, 2013), it is actively being used, its design is often upgraded, and it allows randomized controlled trials to be run easily. Discussions related to the methodology in this paper were based on our experience in applying the methodology on ASSISTments data. More details can be found in Inventado and Scupelli (in press), and Inventado and Scupelli (2015).

The data-driven design pattern production (3D2P) methodology uses an incremental process of prospecting, mining, writing and evaluating patterns. The goal of pattern prospecting is to identify interesting learning outcomes to investigate and to limit the size of the data to investigate (i.e., step 1 & 2). The goal of pattern mining is finding interesting relationships within the set selected by pattern prospecting (i.e., step 3 & 4). The goal of pattern writing is the specification of design patterns that describe problem-solution patterns identified by pattern mining and consulting with stakeholders to ensure their quality (i.e., step 5 & 6). Finally, the goal of pattern evaluation is to assess the quality of design patterns by conducting actual tests for effectiveness (i.e., step 7 & 8).

Figure 1. ASSISTments interface for a word problem. Two hints are shown beneath the word problem.

Figure 2. Data-driven design pattern production (3D2P) methodology (Inventado & Scupelli, in press).

In the first step, data from the online learning system is retrieved and cleaned by removing erroneous data instances and recovering lost information from instances with missing features. The data could be further processed by: transforming its representation (e.g., changing the granularity of the data), adding and deleting new features, or merging it with other data.
sources, which makes it is easier to manipulate or to satisfy the requirements of algorithms that will use the data.

Data analysis is challenging because people have difficulty going through every instance of the data and analysis tools could fail especially if a large data set is used. The goal of step 2 is to investigate only a subset of the data by filtering it using different measures (e.g., answer correctness, answer speed, frustration) according to existing literature or background knowledge to reveal evidence of interesting relationships in the data. It is also a good idea to try different measures and conduct initial explorations on data subsets because they may reveal unexpected relationships in the data.

In step 3, different techniques can be used to find relationships between the features of the filtered data set (e.g., analysing problem text, finding minimum and maximum feature values, measuring correlation between features). It is important to find relationships that occur frequently in the data because design patterns usually refer to quality solutions that address recurring problems in the domain. Analysing the data in step 4 can provide a deeper understanding of the uncovered relationships and can provide insights for formulating hypotheses about student behaviour, learning outcomes, and design decisions. It can also uncover new relationships that can be further investigated, and reveal existing design patterns or related design patterns that are relevant to the system design.

The resulting hypotheses can be used to guide the definition of design patterns in step 5. When a design co-occurs with a desirable learning outcome, it could describe a design pattern solution. Further data analysis could help the pattern author identify the solutions’ corresponding problem, context, forces, consequences, and other properties. On the other hand, designs that co-occur with undesirable learning outcomes indicate the problem that could be addressed by the design pattern. Possible solutions can be identified using the author’s own knowledge, existing literature or suggestions from other stakeholders. Data analysis and the hypothesis can also be used to identify the solution’s corresponding context, forces and consequences, and other properties. Design patterns will need to be evaluated in the succeeding steps of the methodology to ensure their quality.

In step 6, other stakeholders can help evaluate and refine design patterns through shepherding or writing workshops. The data and resulting hypotheses from the previous steps will provide stakeholders with more context, which they can use with their expertise to gauge the quality of design patterns. The pattern author and the stakeholders can work together in continuously refining the pattern until the pattern’s quality is acceptable. It may also be a good idea to collect a significant amount of design patterns before consulting with stakeholders to make better use of time especially when discussions are scheduled in international venues such as workshops or conferences.

Design patterns verified by other stakeholders will probably lead to better outcomes, so in step 7 these patterns are used to change the system’s design. It may be easier to implement related system changes so it helps to collect a few related design patterns before performing the change.

Randomized controlled trials or other similar tests can be conducted in step 8 to compare student performance and learning behaviour with and without the design pattern applied to the system. Design patterns that lead to desirable learning outcomes can be accepted and those that do not can be further refined.

In our experience, some RCTs could not be easily implemented because of system limitations. One such example was the worked examples pattern (Inventado & Scupelli, 2015) (see Appendix A), which could not be tested because it needed significant changes in the interface and underlying architecture of ASSISTments to run. However, the pattern could be applied in other similar systems, which would allow the RCT to be conducted. In the next section, we explore the possibility of incorporating collaboration in the pattern production process to overcome limitations encountered by an individual or a small group of researchers bound by the limitations of the online learning system they are using.

5. Encouraging collaboration in the production of OLS design patterns

Design patterns are often developed by an individual or a small group of individuals, which could be evaluated and refined through writing workshops or focus groups. However, Dearden and Finlay (2006) point out drawbacks in the way design patterns are developed. First, writing workshops usually involve face-to-face meetings, which are expensive especially when they are hosted in international events. Second, incentives are low for evaluating, critiquing, improving and evolving pattern languages. Third, there are issues regarding the ownership of
patterns whenever other authors improve or distribute patterns. Fourth, workshops often involve design pattern authors, but not the stakeholders who will benefit from the patterns (e.g., end users, designers). Bayle et al. (1998) emphasized the need for a genuine community effort, which could address the drawback in current approaches.

Pattern authors usually start defining patterns by pattern mining. There are four methods often used for pattern mining:

Prospecting in pattern-mining workshops could involve the identification of experts to interview and the experiences to investigate. Pattern authors can switch between prospecting and mining as they communicate with experts, and then write and self-evaluate their patterns.

Shepherding and pattern writing workshops can provide better evaluations of the resulting patterns from the aforementioned approaches. External evaluation and feedback can be used to refine design patterns using varying perspectives from different stakeholders.

The discussion on the data-driven approach (i.e., 3DPD methodology) described how each of the 6 steps could be applied on collected data. The addition of the pattern application step and the applied evaluation step allows patterns to be evaluated in specific contexts that could reveal properties that need to be considered. For example, online learning system design patterns produced before the popularity of mobile devices may need to be revised to address changes in the context and forces when a student uses his/her phone to access the online learning system. Explicit feedback about pattern applications can help designers validate their design decisions and help pattern authors continuously refine their patterns.
Exposing the different steps involved in pattern production reveals how pattern authors and other stakeholders can collaborate in the production of patterns. Stakeholders do not need to perform all six steps to produce patterns because other stakeholders can continue performing the remaining steps. For example, stakeholders with expertise in learning and pedagogy (e.g., teachers, learning analytics experts) can help in the pattern-prospecting step by identifying interesting concepts to investigate. Data repositories, such as the PSLC DataShop (Koedinger et al., 2010), contain data and research results that can also be consulted for pattern prospecting. Learning analytics experts can analyse the data to uncover recurring problems and design solutions that can be used by pattern authors to define patterns. Existing design patterns such as, e-learning patterns (Frizell & Hübscher, 2011) or MOOCs patterns (MOOC Design Patterns, 2015) can be applied to existing online learning systems by system designers and developers. Learning analytics experts could then run RCTs to compare the effectiveness of the system (i.e., based on learning outcomes or other measures) with and without using design patterns. Pattern authors can use results from applying their patterns, and evaluations of their patterns in specific contexts to refine pattern definitions. Results from applied pattern evaluations can also help identify new patterns to mine.

Currently, a Wiki is being conceptualized and developed as a repository for fostering collaboration between stakeholders in the production of online learning system design patterns (Open Pattern Repository for Online Learning Systems, 2015). A Wiki was used because it provides a simple mechanism for adding and updating content, managing access, managing changes, communication, and many people are familiar with its functionalities. This is probably why many patterns have been published in Wikis (Kohls, 2013).

In its current state, the repository is serving as a hub for stakeholders to: (a) view and modify contributed online learning system design patterns; (b) track the progress of a pattern; (c) discuss the development of a pattern; (d) contribute to the production of the pattern (i.e., sharing online learning system data, data analysis results, pattern evaluations, observations from pattern applications, evaluations of pattern applications in different environments and domains); and (e) post calls for collaboration in producing a pattern.

6. Discussion

The data-driven design pattern production (3D2P) methodology has many advantages, but also has some limitations. First, it requires more work to perform additional steps for prospecting and evaluating data compared to traditional design pattern processes. Second, it takes more time because there is a need to analyse large data sets to uncover design patterns. Third, the data collected from online learning systems are often incomplete so the patterns uncovered by the platform are bound by the data available. Finally, context plays a very important role because the data collected is very specific. There might be a need to generalize some patterns so they can be used in other systems or domains.

Despite the mentioned limitations, the methodology complements and augments traditional design pattern methods. There are five advantages for using the 3D2P methodology: (a) pattern authors can find interesting relationships in the data more easily compared to searching for it by hand; (b) patterns are not only based on background knowledge and literature but also actual data; (c) feedback from multiple stakeholders are used to refine patterns; (d) pattern quality is validated in actual use; and (e) the methodology can be used incrementally so patterns can be continuously mined and refined as the online learning system evolves over time.

Introducing collaboration in design pattern production provides many advantages. First, when multiple researchers collaborate in writing and refining patterns, they work in parallel, which speeds up the process of generating patterns. This is particularly useful when dealing with large systems or large data sets because the work can be divided among researchers. Using an online repository or similar tools can also make collaboration easier between stakeholders, which can minimize the need for constant face-to-face meetings.

Second, researchers are not required to possess all the skills needed to perform the different steps in the process. For example, some researchers may have expertise in data analytics, but possess minimal knowledge of design patterns. These researchers can focus on data analysis and contribute their hypotheses, which pattern authors can use to mine and write patterns.

There are existing platforms that provide access to data that can be used to define design patterns. For instance, the PSLC DataShop (Koedinger et al., 2010) contains a huge amount of
data from various online learning systems and provides tools to access and analyse the data. ASSISTments grants researchers access to its data and the ability to run randomized controlled trials (Heffernan & Heffernan, 2014).

Moreover, when patterns are applied and evaluated in existing systems, other stakeholders become more involved. For example, teachers can be asked to use patterns when creating content and students can use versions of the system with the adapted design patterns. Evaluations based on teacher comments, and resulting student behaviour and performance can be used to refine design patterns further.

Third, any pattern analysis, evaluation or refinement is shared between all researchers investigating that pattern. There is more incentive for researchers to collaborate because they will mutually benefit from each other’s work and their effort will result in research and design patterns that are up-to-date. Collaborating with a team of researchers also promotes feelings of belongingness, which could motivate researchers to contribute their work, and could shift pattern authors’ views from pattern ownership to pattern co-authorship.

Fourth, the frequency of pattern usage in different systems could describe its generalizability, and patterns with good evaluations would indicate its robustness. Pattern authors or other researchers can decide to refine the patterns to make it more robust or decide to create a parent pattern if needed. Patterns tested in one system or domain can be modified to generalize across domains or systems.

Finally, online learning system designers will have access to more patterns, which they can use to create and maintain their systems. As more designers get involved and use design patterns, the standards of online learning system quality can also be elevated.

Developing an open repository to foster the collaboration between stakeholders offers many advantages. First, it can serve as a hub for locating and contributing patterns. Metadata about the patterns could even allow searching for patterns outside the repository (i.e., through links to related patterns in literature or other repositories). Second, it can serve as a common ground for researchers to talk about: (a) patterns to write (i.e., using hypotheses from data analysis), (b) patterns to evaluate (i.e., using unevaluated patterns), and (c) patterns that can be used to design a system or resolve system issues (i.e., using information about pattern applications). Third, it can give a richer description of design patterns, which can help designers select and apply appropriate patterns to their projects (e.g., evidence used to define the pattern, known successful applications of the pattern, issues in applying the pattern). Fourth, the pattern repository could describe the evolution of each pattern as it is refined over time. Proper documentation could also provide proper attribution to authors who contributed to its development.

7. Summary and future work

Producing design patterns for online learning systems is challenging because of its multi-disciplinary nature, design complexity, continuously changing components and content, and the diversity of its users. The 3D2P approach addresses these challenges by using data to perform pattern prospecting, pattern mining, pattern writing, pattern evaluation, pattern application, and pattern application evaluation. It uses an incremental process so that design patterns can be produced and refined as the system and its stakeholders evolve.

Promoting collaboration in pattern production allows researchers to divide the workload and speed up the process of producing design patterns. It does not require researchers to learn specific skills to collaborate, so they can just utilize the expertise they already possess. Researchers benefit from each one’s contribution because they share in the development of the design patterns and their contributions can be properly attributed. Collaboration also encourages patterns to be applied in different domains, which allows designers to assess the generalizability and robustness of patterns across systems and domains. Most importantly, promoting the use of design patterns in online learning systems elevates the standards of online learning system development.

Although the platform is being tested for online learning system design patterns, it can easily be used in other systems and domains. For instance, design patterns can be produced for online services to improve and maintain the quality of user experiences across different platforms and devices.

Currently, an open pattern repository is being developed to facilitate collaboration between stakeholders (Open Pattern Repository for Online Learning Systems, 2015). We are inviting other researchers to help us develop this repository and build a community that will contribute to the pattern production process through pattern prospecting, mining, writing, evaluation, application, and applied evaluation.
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Appendix A: Design Patterns

Worked examples (Inventado & Scupelli, 2015)

Platforms tested: ASSISTments

Problem type: Mathematics word problem or equation solving

Evidence: Data showed that students gamed the system when they did not know how to answer a problem.

Context: Teachers use ASSISTments to select the problems in an assignment, specify the sequence and conditions for presenting questions to students, and assign the homework or activity to their students.

Forces:

1. Teachers and content experts add problems into ASSISTments with corresponding answers and feedback (i.e., hints, scaffolds, bug messages).

2. Students can have sufficient background knowledge to solve a problem, but have no idea how to apply it (e.g., a student understands the concept of division but may not know how to split the bill at a restaurant).

3. Problem definitions (e.g., difficulty, presentation, wording, sequence) affect students’ learning experiences.

Problem: To instruct students how to solve a problem that they do not know how to solve.

Solution: Present a worked example similar to the problem that the student is solving.

Consequences:

Benefits:

- Students will learn how to solve problems of the same type as the worked example.

- Students will less likely game the system or disengage from the homework because they know what to do.

Liability:

- Teachers or content experts will need to provide a worked example for the problem aside from other feedback.

- ASSISTments will need to be modified to provide an interface for showing worked examples (i.e., as opposed to requesting for multiple hints)

Example:

When a teacher creates a math problem in ASSISTments, he/she will be asked to provide the math problem, the correct answer, the hints, and also a worked example. In the interface, students who do not have an idea how to solve a problem can click a “worked example button”, which will then show the worked example provided by the teacher. The student can study the worked example to help him/her solve the next questions more easily.

Related Patterns: Worked examples organize the solution into a series of steps much like Wizard (Tidwell, 2011).

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