Developing Instructor Training for Diverse & Scaled Contexts: A Learning Engineering Challenge

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***Abstract*— Learning engineering provides both a practice and process for solving educational challenges. While the circumstances of each challenge require a unique application of learning engineering, the learning engineering process was designed in such a way to provide guidance across a broad range of contexts. In this paper, the learning engineering process is articulated from the perspective of the developers of online courseware used in higher education. Within this use-case, we exemplify how an initial learning engineering process for the creation of the courseware provided a starting point for iteration, and in this instance, the beginning of an entirely new process on instructor enactment of that courseware. Whereas the initial challenge was to develop the courseware environment, this emergent challenge now focuses on understanding and addressing contextual factors that affect the successful instructor application of the courseware learning environment at scale.**

Keywords-learning engineering; learning engineering process, instructor training; teaching and learning; learning technology; courseware.

I. INTRODUCTION

Learning engineering is defined by the IEEE IC Industry Consortium of Learning Engineering (ICICLE) [4] as "a process and practice that applies the learning sciences using human-centered engineering design methodologies and data-informed decision making to support learners and their development." Learning engineering is an interdisciplinary practice that incorporates the learning sciences, data science, curriculum research, game design, and more, providing an infrastructure for design research, analytics, and iterative improvement [2]. A learning engineering process model was first developed through initial work in the ICICLE design special interest group [6] with later iterations discussed herein [7]. The learning engineering process model is cyclical in form to reflect the concurrence of work required and the constant iterations that occur in trying to solve any educational challenge. This learning engineering process itself is broadly described as the applications for its use are equally varied. There are many types of educational challenges to be solved and as many groups working to solve them. The learning engineering process provides an organizational workflow that any person or team can apply to their challenge. As shown in Fig. 1, the challenge to improve learning or learning environments is at the center of the model. Investigation, creation, and implementation are all connected in the process of designing and enacting the solution to this challenge. Yet each of these phases of the cycle can also inform the challenge and solution in their own iterative cycles. Lastly, the context, learners, and team all contribute to variations in how challenge solutions can be scaled or not depending on the almost limitless varied settings such solutions might be deployed.

Figure 1. The learning engineering process (CC by Aaron Kessler).

This process can be broadly illustrated through the example of courseware development at Acrobatiq (Fig. 2). The challenge at the center of the learning engineering process was to create courseware that applied established learning science research to provide an effective digital learning environment for students. The context for this challenge was shaped by Acrobatiq's origins from Carnegie Mellon University's Open Learning Initiative and the research in online learning established there (e.g., [8][9]. The goal was to apply that research to a courseware environment that could be used by students across higher education institutions at large. The team consisted of learning

Figure 2. The learning engineering process with the central challenge of creating online courseware.

engineers, software engineers, subject matter experts, project managers, and data scientists. This team collectively contributed to the creation phase of the process. During this phase, the courseware platform and content were created—which consisted of many iterative cycles of design, development, and data instrumentation.

Once ready, the process moved on to the implementation phase wherein the courseware learning environment was used by instructors teaching at community colleges and four-year institutions. Data were collected by the platform as students engaged with the courseware, and these data were then analyzed during the investigation phase. The data analysis of this investigation stage provided examples of effective learning methods such as adaptivity [16] and replication of findings of previous research on the learn by doing method [17]. The investigation phase also uncovered areas in need of improvement, which created additional iterations of the learning engineering process. For example, data analysis showed low student use of the adaptive activities across course subjects and educational institutions. Identifying this issue initiated an iterative improvement cycle wherein a change was made in the location and delivery design of the activity. This change was then re-implemented with students, and further data analysis showed this solved the challenge, and completed that iteration of the original learning engineering process [15]. It should be noted that these analyses and iterations did not occur one at a time, but rather as concurrent processes.

Yet other investigations of the courseware usage identified a new challenge altogether. An analysis of the same Probability and Statistics courseware used across a state system of community colleges and universities identified that different instructor implementation policies and practices affected student engagement with the courseware [18]. This analysis revealed the need for a new learning engineering process where the challenge was no longer developing effective courseware, but rather facilitating the instructor's application of the courseware across a large scale of unique learning contexts, as seen in Fig. 3.

When we consider the challenge that no two educational settings are the same, it becomes clear that the instructor's application of any learning resource, technology, or intervention could result in varied outcomes across settings. Successful practices in one specific learning situation may not be successful in a different environment. This work seeks to accomplish two goals. The first is to show how multiple learning engineering challenges and processes can evolve from a single original challenge. The second is to focus on the contextual factors that contribute to how instructors enact any learning technology, resource, or treatment and how the learning engineering process can be applied to solve this challenge. The courseware example highlights the learning engineering process used to design a solution to better train instructors in a scalable way, with the goal of supporting effective implementation of the courseware in diverse and distributed environments. Situating this case in cycles of the iterative learning engineering process exemplifies how one cycle of work can result in clear points of identifying and/or redefining the central challenge addressed through the learning engineering process.

II. The Learning Engineering Challenge: Context-Specific Training at Scale

Every opportunity a student has to learn is one in which a learning experience—including an instructional plan—was purposefully designed and implemented. Whether this occurs in a traditional classroom between a teacher and students, an after-school program, or an online training for lifelong learners, each learning interaction is an implementation of a designed learning experience. The implementation of an instructional plan has the potential to drastically impact how students engage with the learning resource and develop the knowledge at the core of the learning experience. Beyond that, it can also impact the way in which students are able to demonstrate their understanding through assessments and activities. Recent examples of research on digital learning resources showcase the crucial role of the educator for the implementation of technology in the classroom. A study investigating the teachers' role implementing a cognitive tutor for math education for fifth to eighth graders identified different patterns of teacher/student/cognitive tutor interactions that could impact student performance in computer-directed learning environments [5]. Research on an instructor's implementation practices of adaptive courseware in higher education showcased how specific changes to course policies and teaching practice strongly impacted student engagement and exam scores [3].

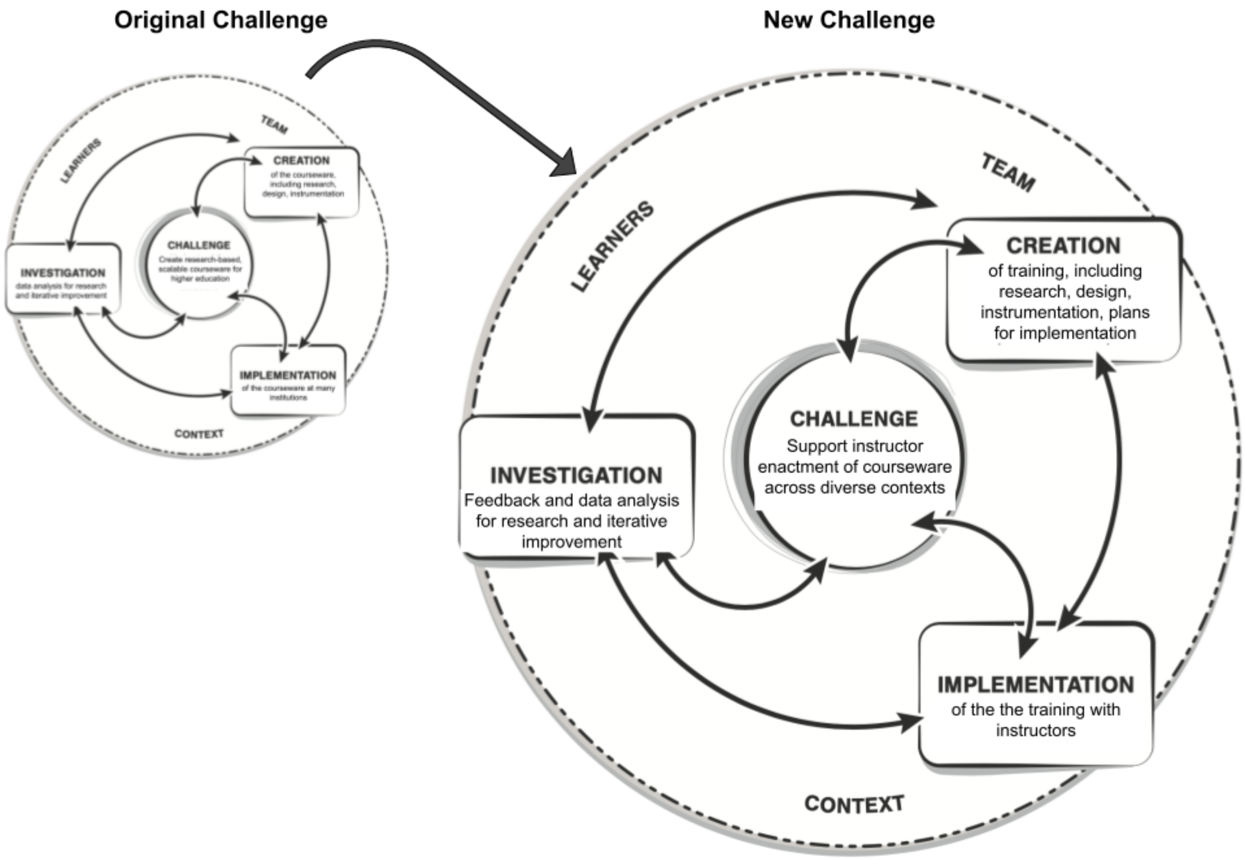

Figure 3. The original challenge of creating courseware leads to a new challenge—supporting instructor enactment of courseware across diverse environments.

The discussion of implementation is not new, with efforts to define and describe its importance in educational research going back decades [1]. Implementation—and the level of fidelity to the intended implementation plan—is a rigorously applied practice in the healthcare field where adherence to a implementation of a treatment is highly relevant to outcomes, yet historically has been less frequently applied in education to evaluate the efficacy or effectiveness of an educational treatment [11]. This concept of implementation is relevant at its most basic level to the use of courseware as a learning resource in the classroom: in order to help students achieve the benefits of the courseware (i.e., learn by doing or adaptivity), they must actually *use* those features. However, unlike the example of controlled lab experiments in the healthcare field discussed by [11], all educational natural learning contexts will have variability that cannot fit a single prescribed implementation plan. The learning engineering process can help to address this challenge by unpacking the contextual factors surrounding the implementation of courseware at scale.

Before continuing the unpacking of this learning engineering challenge, an issue of language must be addressed. As described in the literature above, implementation as a term is commonly used to refer to the application of a plan or treatment either in a controlled experiment or natural learning settings. However, this same term is used as the label for the stage of the learning engineering process in which the solution is deployed. In this work, the challenge of the learning engineering process (the implementation of the courseware across varied educational settings) and the implementation stage (in which the solution to this challenge is implemented) will become easily confused. Therefore, in this work, implementation will refer to the learning engineering stage, and the central challenge will be referred to as the instructor's application or enactment of the courseware.

A. *Challenge Context: Variation in Instructor Setting*

In the original learning engineering process discussed above, the central challenge was to develop courseware that could serve students and instructors in a wide variety of educational settings. Yet the variation in the implementation phase of the learning engineering process—wherein instructors utilized the courseware in their teaching practice in widely different ways—resulted in significant differences in student engagement and outcomes. This realized variability presents the opportunity for establishing a second challenge, not about the development of the courseware itself, but rather the application of it in the classroom. Given that the courseware was designed to be agnostic to setting, it cannot be differentiated for each use-case. Therefore, a potential set of solutions to this challenge required exploration outside of the technology itself and as such involve a new learning engineering process described in greater detail below.

Part of the learning engineering process is the basic principle that learning itself is situated within specific contexts. Consider first the complexities educators are faced with for teaching and learning. The courseware as a learning resource may be a new environment for instructors compared to traditional textbooks, or even etexts. In addition to the courseware, instructors likely also use a learning management system and other teaching and learning tools that make up the learning ecosystem for a course. Teaching models (such as traditional, blended, flipped-blended) vary by instructor and interact with teaching modality, which has expanded from face-to-face to include hybrid and fully online learning modes with increasing frequency. These options for teaching models and resources are further complicated once considering their interaction with the specific group of learners being instructed. The number of students as well as their characteristics all contribute to the unique context in which an instructor applies their instructional plan. The instructor's use of courseware (designed to be context agnostic) within varied and unknowable settings is the context for the second learning engineering challenge (Fig. 3).

B. Designing a Solution

As seen in Fig. 1, the design phase of the learning engineering process encompasses several tasks necessary for the development of the solution. The relevant research from the learning sciences should be consulted for the design and development of the solution, with data instrumentation incorporated into both of those tasks. Finally, plans for the implementation of the solution are created [13].

1) Design

One designed solution to the challenge of effectively utilizing courseware across many diverse settings is instructor training and support. While there could be any number of other solutions, the influence of instructor choices on student participation and outcomes is an established relationship that can be leveraged toward optimum courseware usage, and the instructor is also able to adjust enactment plans to account for their specific setting of teaching and learning. Before beginning to design and develop this instructor training and support solution, the existing research and knowledge base on instructor policies and practices that are beneficial engagement and outcomes should be consulted. Research can surface a set of practices to consider recommending for instructors—and sometimes a set of practices to avoid. For example, the teaching model (traditional, blended, flipped-blended, etc.) is known to influence student outcomes [10], and therefore is a factor to consider for the application of courseware as the learning resource for a class. Simply using the courseware and completing the formative practice garners benefits for students, so assigning completion points as part of the overall course grade could become a recommended practice [3]. Another strategy to recommend could be to use the data from the instructor dashboards to facilitate interventions between instructors and students or help tailor additional instruction around content students struggled with. A community college case study of instructors using courseware identified that the data dashboards helped identify at-risk students and facilitated a flipped-blended model for in-person and remote learning [14]. Research on successful practices for teaching and learning with digital resources can provide a starting point for the design and development of a solution [13][7].

2) Instrumentation

Instrumentation in the learning engineering process is when data collection is designed, developed, and implemented. This instrumentation step is part of the creation phase because preparing for what data will be needed for analysis and how that data will be collected must happen concurrently with the design and development of the solution. While the courseware collects data as students are learning, this does not help address the challenge of assisting instructors' use of courseware within their specific teaching and learning setting. Therefore, gathering data to explore and understand their situated learning environment should become part of the solution. The focus on instructors and their needs for teaching when instrumenting a solution is aligned with the human-centered approach of learning engineering. "Human-centered engineering design means designing from the perspective of humans who will be interacting with implemented designs" [12, p. 83]. Identifying core variations in teaching and learning that instructors have to navigate in order to instrument and implement the solution maintains the instructors at the heart of the solution.

Instructors will need to identify factors that contribute to how they might enact this learning resource. This could include identifying the teaching model, modality, number of students, student characteristics, course category (major/non-major, elective, required, etc.), and graded components of the course. One avenue for standardized data collection would be surveys for the instructor to complete prior to receiving their training materials (the solution in development). These factors all contribute to how the courseware could be most successfully utilized and, therefore, are necessary for instrumentation as inputs for tailoring training for instructors.

Instrumentation should also include gathering success criteria and the subsequent data necessary to determine if those success criteria were met. This type of instrumentation can be easy to overlook but is key to maintaining a cohesive vision for the goals of using courseware as a learning resource across all stakeholders involved. This also means that this instrumentation will need to consider several distinct groups of stakeholders. To design for instrumentation at different levels, the first step is identifying the relevant groups. Students are the primary users of the courseware, as it is their learning resource, and therefore defining what success looks like to them is key. Depending on the situation, this could range from simply engaging with the courseware to increased learning outcomes on assessments. Also consider the difference between what students would identify as their successful use of the courseware versus what the instructor would define as student success. The instructor's goals likely would include success criteria for students—such as improved grades—but may also include goals for themself such as shifting the teaching model, identifying and intervening with at-risk students, or tailoring instruction based on data. There may also be additional stakeholders further removed from the active use of the courseware who have a vested interest in its use and therefore additional success criteria, such as administrators. Their goals may be more broadly related to success and retention metrics. Identifying each group of stakeholders for the courseware and their goals allows for the instrumentation of data collection to determine how those goals are being met. Without this instrumentation planning, design, and development, there could be a lack of clarity as to whether the courseware was successfully applied in a specific context to meet specific goals and, furthermore, what iterative improvements may be needed to meet those goals in the future.

3) *Plan for Implementation*

With the research base established and instrumentation stakeholders understood, the design and development work can move out of initial stages and continue concurrently. The challenge of how to train and support instructors to implement courseware effectively in incredibly varied settings requires a solution that can address these situational factors (as many as feasible) in a scalable way. As courseware is designed as a learning resource for students, training must be designed as a learning resource for instructors. Each major contextual factor identified could be addressed as a topic with successful practices established in educational research combined with case study successes to address common variability in each topic. Preparing for known variations in teaching environments can provide a stand-alone resource, but planning for unanticipated cases should also be part of the solution design. Direct instructor training would be beneficial not only for identifying these special cases, but also to execute the instrumentation plan described for collecting data on context and stakeholder goals. Furthermore, just as instructors need to tailor their use of courseware depending on whether they have 20 or 200 students, so too would the instructor implementation training and support plan need to adapt depending on the number of instructors. Designing different training implementation plans depending on the number of instructors and modality of training is another component of the creation phase.

C. *Implementation and Investigation*

Once the instructor training solution has been designed, instrumented, and developed, it is time to implement it with instructors. The implementation of this solution may begin with a few instructors as a pilot or with a large number of instructors if delivery at scale is possible. No matter the scale, data collected from instructors on their unique teaching factors will begin to inform the investigation of the solution. For example, an instructor teaching a traditional face-to-face semester course and an instructor teaching an asynchronous online course will both experience the training solution and use it to attempt to optimize their application of the courseware in their unique setting. Combining the data collected from their teaching context with the student engagement and outcome data collected from the courseware will begin to inform how successful the training solution was in supporting instructors. Additionally, the contextual factors provided by instructors would inform new content or changes to the training solution to incrementally increase the factors covered, iteratively improving the solution. Feedback from instructors on success metrics would also surface information in the investigation phase of the learning engineering process that could lead to new instructor enactment suggestions in the training. Ideally, each implementation of the training would provide data to inform further improvements to the solution, which would hopefully continuously improve instructor use of courseware in their educational context for the benefit of student learning.

III. CONCLUSION

Learning engineering as a process is used in many different contexts to solve many different educational challenges. However, it is unlikely a challenge would be perfectly solved after one single cycle of the learning engineering process. Instead, the process is designed and intended to support many iterations of the process to continuously improve the solution, while also being aware that sub-cycles or entirely new but related learning engineering challenges may arise. Clearly identifying each educational challenge at the center of each learning engineering process and how multiple separate or sub-cycles relate will benefit the entire learning engineering team tasked with solving the challenge(s) most effectively.

The example of how multiple related learning engineering challenges can develop expressed here was chosen to highlight a related challenge often overlooked: the highly varied educational settings within which educational technology and interventions are used. In this example, the development of educational technology was the primary learning engineering challenge accomplished through the learning engineering process, but how to help instructors teaching in such varied circumstances became an entirely new educational challenge to be solved. The need to support instructors to enact learning technology or educational interventions in a meaningful way within their unique teaching and learning circumstances is a nearly universal challenge. Even with educational technology that conforms to the latest research in the learning sciences, the enactment of that resource in a specific educational setting will strongly inform student engagement and outcomes with that resource. This challenge is one that all creators and developers of educational solutions should consider carefully and attempt to solve using the iterations of the learning engineering process.

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