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Data-Informed Course Improvement: The Application of Learning Engineering in the Classroom

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Abstract: Learning Engineering is a practice and process that can be used by any teacher in the classroom to apply the learning sciences in their instructional design, while collecting and analyzing data to determine the effectiveness of their interventions. This practice-oriented paper reports on three examples of the learning engineering approach applied to course improvements in higher education to address self-regulated learning, social presence, and interleaving.

Learning engineering can be intimidating for the typical classroom teacher. The word “learning” is familiar, but the word “engineering” may be misunderstood or may make an educator feel unqualified to explore this approach. Much of the literature on learning engineering describes large teams engaged in a project (Dede et al., 2018), scaling up learning solutions (Saxberg, 2017), or utilizing the approach by educational software developers (Goodell, 2022). However, the good news for teachers is that the learning engineering process and practice can be applied on a smaller scale in the individual classroom by any teacher, at any level, and in any subject area, who wants to improve learning outcomes for her or his students. By applying the learning sciences to our instruction, planning for collection and use of data, and understanding our learners and the effect of a unique context, we can make our classrooms more effective, equitable, and enjoyable. These are the processes involved in learning engineering, and teachers may find this systematic approach to be attainable and beneficial. In this paper, I will provide a brief overview of learning engineering and then share how I have used this approach in my own classes with promising results.

Learning Engineering

The IEEE industry consortium on learning engineering (ICICLE) defines learning engineering 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” (Goodell, 2022, p. 10.). While learning engineering teams do exist in some organizations and there are increasingly more job postings for the role of learning engineer (V. R. Lee, 2022), this approach can be used at a smaller scale. All that is required is an understanding of the learning sciences, familiarity with some engineering principles, and a willingness to be adaptable in your instruction based on the data from your learners to iterate improvements.

The science of learning can be helpful to instructors who are using evidence-based practices in their teaching to help them understand why these practices are effective and in what circumstances (Daniel, 2012; McMurtrie, 2022). One critique of the science of learning is that the studies are often too controlled, conducted in a lab setting or with strict controls in a classroom environment (Daniel & Chew, 2013). The learning sciences have brought principles to educators such as the role of prior knowledge, skills, and beliefs; desirable difficulties; error management; feedback; active learning; retrieval practice; spacing and interleaving; metacognition; self-regulated learning; multimedia principles; and problem solving (Benassi et al., 2014). While learning sciences researchers often apply theory in practice in ways that encompass the whole learner (V. R. Lee, 2022), learning engineering allows us to examine these concepts in a specific context with a unique group of learners to understand the limits and applicability of these phenomena.

Barr et al. explained that “engineering is the application of creativity and science to solve problems, and learning engineering is the application of the learning sciences to creatively solve problems for learners and learning” (in Goodell, 2022, p. 131). They noted several principles of engineering that can be applied to designing solutions to learning challenges, including addressing specific problems, end users who are intended to benefit from the solution, testability, maintainability, integrity, well-defined external integration, ethics, and management (p. 131). Learning engineers use systems thinking to explore modular design, constraints and tolerances, operating conditions, trade-off analysis, and feedback loops. Engineers and research scientists often use data differently: while the learning sciences are often focused on group means, learning engineers probe outliers and individual cases to explore boundary conditions (Goodell, 2022).

Use Cases

I teach at an institution that serves nontraditional learners in distance education. My students often have not been in a classroom for many years, have negative past experiences with school, have work and caretaking responsibilities outside of classes, and often face other life stressors that place them at risk for not completing a course. In order to address these challenges, I turned to the learning sciences. I now provide three use cases from several semesters of an introductory computer applications class illustrating how I have utilized learning engineering in my practice as an educator. Each of these consists of the core components of learning engineering: a learning problem or challenge, the design of a solution that applies the learning sciences, implementation with data collection, and investigation with data analysis, including iterating improved designs (Goodell, 2022).

Self-Regulated Learning

Learning challenge. Traditional face-to-face classes often provide the on demand supports and structures that regulate student learning, but these can be absent in online learning unless intentionally designed, requiring students to regulate their own learning. First generation students have significantly lower levels of self-regulated learning skills (Williams & Hellman, 2004), and participating in online learning does not necessarily improve these skills (Barnard-Brak et al., 2010). Deficits in self-regulated learning skills can negatively impact distance learners (Bol & Garner, 2011), especially adults (K. Lee et al., 2019). I have seen this in my own learners.

Design solution. Pintich's (2004) model of self-regulated learning includes four phases (plan, monitor, control, and reflect) and four areas (cognitive, affective, behavior, context). Using this framework, I included a section in my course syllabi with tips for success that included questions students can ask themselves to regulate their learning, such as, "How long will it take me to complete this assignment?" and "How can I make this assignment meaningful to me?" I modeled task analysis for students by showing them how I would plan out my week if I were taking this class, including learning tasks in addition to completion of assigned and graded work. I displayed a sample weekly routine in calendar format with tasks spread out over the course of the week to encourage spaced practice (Dunlosky et al., 2013) with estimated times for each task so that students could plan within their busy schedules. I created separate Google Docs for each student that included four reflection questions they would complete weekly as an exit ticket. The document included a table with one question in each column and a new student response in a row for each week of the semester. Students were instructed to reflect on their learning experiences but not to spend more than five minutes on the task. The questions were:

1. What did I learn or what questions do I have? (cognitive)
2. How do I feel about my learning experiences this week and why is what I learned important to me? (affective)
3. What did I do that helped me succeed or what should I do differently? (behavior)
4. What was helpful about the structure of the class or the way I interacted with others? (context)

Data collection and analysis. By explaining the purpose and benefits of completing the optional learning tasks, such as practice quizzes and studying, as well as helping students to map them out into their schedule, I did see an increase in the number of students who completed those tasks. When not all students were completing the exit tickets, I assigned five percent of the final grade to completion and began tagging students immediately who did not complete it. This led to more than 90% compliance over the course of the semester with this short weekly assignment, an increase from prior semesters. Every week, I was able to see what each individual student found important and where they were confused, what strategies they were using for learning, and where I might make improvements to the course. By responding to student reflections with the commenting tool, I was able to tag them with resources and suggestions or ask questions for clarification on issues or suggestions. Students could reply to these comments from their email, which often led to ongoing conversations in the document throughout the semester. Students often provided excellent suggestions in their exit tickets for small changes I could make in class to improve their learning, such as providing assignments for multi-week modules in a calendar format instead of just a checklist. Whenever I try a new technique, I now ask for feedback from students in their exit ticket.

Social Presence

Learning challenge. Social presence of any kind online can be defined as "the degree of feeling emotionally connected to another intellectual entity through computer mediated communication" (Sung & Mayer, 2012, pp. 1738–1739). Indicators of social presence can be affective (expressions of emotions or mood), interactive (acknowledgement of another), and cohesive (things that build or sustain group cohesion) (Rourke et al., 1999). Adult learners find teaching presence to be essential for their learning and seek deep interactions with content rather than surface learning, with peer interactions a bonus (Angelaki & Mavroidis, 2013; Ke, 2010). Mayer (2014) suggested that this connection helps to foster deeper processing during learning.

While the exit tickets had helped me to develop relationships with each individual student, I found that students in my synchronous online classes were reluctant to communicate with each other or speak up in front of the whole class. Teacher immediacy behaviors have been shown to have a positive impact on learner emotions and learning gains (Ge et al., 2019; Liu, 2021), while emotions (Plass & Kalyuga, 2019) and social connections are integral to the learning process (National Academies of Sciences, Engineering, and Medicine, 2018). To address the social distance and emotional connection in my classes, I looked for strategies that would help students to develop learning relationships with me and each other.

Design solution. One strategy I implemented was an opportunity for bonding in the first class meeting. I presented to the students my commitments to them: share tips for being a successful student, be patient with explaining the same thing in many ways, care about you and your experience in this class, make class meetings worthwhile, help you meet your learning goals, and appreciate your efforts. I then split the class into breakout rooms to introduce themselves to a smaller group, asking them to make commitments to each other. I followed this up with other teacher immediacy behaviors throughout the semester, such as referring to students by name, using a more informal and relaxed meeting platform (www.kumospace.com), using "we" and "our" language, narrating my thinking as I worked through problems, using cute praise memes in assignment feedback, and having informal conversations with students at the beginning of class.

Data collection and analysis. Students often commented in the weekly exit tickets described above how much they enjoyed playing review games together and working with a partner on an assignment because they were able to help each other and explain concepts in a different way. This was a marked change to the comments I had seen in earlier semesters where students rarely referenced one another. By setting aside approximately an hour per course each week to review exit tickets, I was able to maximize my personal connection with each individual student. The inclusion of other teacher immediacy behavior strategies and the frequent partner and small group work appeared to make the students more at ease as evidenced by comments in the weekly exit tickets, more students turning on their cameras during course meetings, more interactivity in the course chat, and more engagement and small talk during small group work. In future iterations, I will make these strategies explicit to the students and ask them to reflect on the impact to their learning experience.

Interleaving

Learning challenge. One thing that often frustrated me when teaching a computer applications class was that students frequently forgot content from the beginning of the semester by the time we reviewed for the exam. The curriculum consisted of a module on Windows, three modules each of Word, PowerPoint, and Excel, and a short module on databases. After learning about interleaving, and it occurred to me that it might be possible to switch up my coverage of the curriculum to help address this learning challenge. Interleaving is the act of mixing together study of multiple related topics rather than learning individual topics one at a time (Birnbaum et al., 2013).

Design solution. In the next semester, I planned to rotate the applications each week, rather than teaching them in a block. In the introduction to the course, I told the students about this approach and that I hoped it would help them to see the connections between all of the Office applications while mitigating the forgetting that often happens. I planned to examine the quality of assignment submissions, quiz scores, and comments from students in weekly exit tickets.

Data collection and analysis. An analysis of the data revealed a clear improvement in the quality of assignments that were submitted and a slight increase in weekly quiz scores. Students became more focused on the commonalities between the Office applications, such as the structure of the window, the tools on the ribbon, and using features like SmartArt and image editing. When reviewing for the final exam, students had retained more information on features of Word because they had utilized the program every three weeks throughout the semester, rather than in only three weeks at the beginning of the semester.

Conclusion

Using evidence-informed strategies in the classroom can be beneficial to learners, but the use of learning engineering has taught me the value of using evidence-*generating* strategies to understand my students, their learning experiences, and their learning outcomes. In this practice-oriented paper, I described three scenarios of course redesign in my classes where I used the learning engineering approach: I identified a learning challenge, applied the learning sciences to an instructional solution, collected data, and analyzed the data for evidence of effectiveness of the new strategy. In most cases, I made small changes to iterate the design throughout the semester based on the student data. While the emerging field of learning engineering primarily focuses on developing learning solutions on a larger scale, this process and practice can be utilized by any educator to improve learning experiences for their students.

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