Paper ID #36538

Development, Implementation, Refining and Revising of Adaptive Platform Lessons for an Engineering Course

Autar Kaw (Professor)

Autar Kaw is a professor of mechanical engineering at the University of South Florida. He is a recipient of the 2012 U.S. Professor of the Year Award (doctoral and research universities) from the Council for Advancement and Support of Education and Carnegie Foundation for Advancement of Teaching. His primary scholarly interests are in engineering education research, adaptive, blended, and flipped learning, open courseware development, composite materials mechanics, and higher education's state and future. His work in these areas has been funded by the National Science Foundation, Air Force Office of Scientific Research, Florida Department of Transportation, and Wright Patterson Air Force Base. Funded by National Science Foundation, under his leadership, he and his colleagues from around the nation have developed, implemented, refined, and assessed online resources for open courseware in Numerical Methods (http://nm.MathForCollege.com). This courseware annually receives 1,000,000+ page views, 2,000,000+ views of the YouTube lectures, and 90,000+ visitors to the "numerical methods guy" blog. This body of work has also been used to measure the impact of the flipped, blended, and adaptive settings on how well engineering students learn content, develop group-work skills and perceive their learning environment. He has written more than 150 refereed technical papers, and his opinion editorials have appeared in the Tampa Bay Times, the Tampa Tribune, and the Chronicle Vitae.

Ali Yalcin (Assistant Professor)

Ali Yalcin, is an Associate Professor of Industrial and Management Systems in the College of Engineering at the University of South Florida. He is the co-founder of Collaborative for Research & Education in Aging and Technology. Previously he was part of the leadership team who founded the Patel College of Global Sustainability at USF

Professor of EE, AAMU

Renee M Clark (Director of Assessment)

Renee Clark is Research Assistant Professor of Industrial Engineering and Director of Assessment for the Engineering Education Research Center (EERC) in the Swanson School of Engineering at the University of Pittsburgh. She conducts education research that focuses on active learning and engineering professional development. Renee's current research includes the use of adaptive learning and systematic reflection in the mechanical engineering flipped classroom to drive pre-class preparation and metacognitive development, respectively. She received the Ph.D. in Industrial Engineering from the University of Pittsburgh and the MS in Mechanical Engineering from Case Western. She has 30 years of experience as an engineer, IT analyst, and researcher in industry and academia. She completed her post-doctoral studies in engineering education at the University of Pittsburgh.

Development, Implementation, Refining and Revising of Adaptive Platform Lessons for an Engineering Course

1. Introduction

Since the high-profile meta-analyses (Freeman et al., 2014, Theobald et al., 2020) of undergraduate STEM courses, active learning has become a standard in higher education pedagogy. One way to provide active learning is through flipped learning - "a pedagogical approach in which direct instruction moves from the group learning space to the individual learning space, and the resulting group space is transformed into a dynamic, interactive learning environment where the educator guides students as they apply concepts and engage creatively in the subject matter" (Talbert, 2017, Flip Learning, 2019).

A typical flipped classroom involves pre-class, in-class, and post-class learning. The pre-class learning is done individually by the student and generally includes some combination of video lectures, textbook content, and online assessment but falls under the one-size-fits-all (i.e., non-personalized) approach. The pre-class learning gets the student ready for the in-class segment, which involves well-thought-out conceptual and procedural exercises to improve the level of learning of students and mini-lectures to clarify student misconceptions and difficulties with the learning materials. The in-class segment is followed by post-class learning, which includes completing the topic, solving problem sets from the textbook, and projects to improve students' higher-level thinking skills.

Flipped classes have been found to be relatively successful when compared to the traditional lecture modality. Recent meta-analyses (Talbert, 2018, Lag and Sale, 2019) based on research articles in eight electronic reference databases show an average effect size[1] of $d=0.24$ for cognitive learning in favor of flipped classes over traditional ones. The average effect size on student satisfaction was lower at $d=0.16$. A metastudy of 63 papers for K-12 students from 2021 by Shao and Liu shows an average effect size of $d=0.63$, finding better results for classes smaller than 120 students and humanities courses. Also, a meta-study by Birgili et al. (2021) shows similar increases in student performance and affective outcomes of engineering students.

Flipped classrooms do indeed have some challenges, though. One significant challenge is finding suitable pre-class learning activities to improve student preparation and the subsequent classroom environment, including student engagement (Shekhar et al., 2019, Finelli et al., 2018, Tharayil et al., 2018). Many students come unprepared to the classroom and adversely affect the group experience. These challenges were experienced by the authors of this paper, who teach a course in Numerical Methods. To address this challenge of under-preparation with pre-class learning materials, we developed adaptive learning lessons to remedy the one-size-fits-all approach to pre-class learning.

---

[1] Effect size is the difference between an experimental and a control group and is measured as (Mean of the experimental group–Mean of the control group)/(Standard Deviation). Rules of thumb for effect sizes being small or large should be based on comparable studies in the field. An average effect size for education interventions that are published in the literature is $d=0.38$ (Hattie, 2008).

Adaptive lessons delivered via online platforms provide personalized and flexible learning by monitoring student progress and performance. Using learning algorithms, the platform subsequently provides an individualized learning path and motivates students optimally. Adaptive lesson platforms (ALPs) have shown their power on a large scale in undergraduate STEM education. For example, using ALPs, Georgia State University reduced the DFW (D and F grades and withdrawals) rate in college algebra from 43% to 21% (Quinton, 2013) in a sample of 7,500 students and in developmental mathematics courses (ACT, 2019, Knewton, 2019), ASU reduced the DFW rate from 16% to 7% in a sample of 2,000 students.

The use of adaptive lessons in engineering flipped classrooms is limited, though. Kakosimos (2015) used adaptive learning in a flipped course in a Chemical Engineering Fluid Operations course. However, the control group was from a different course, so a direct comparison of the effectiveness was not possible. The first and last author of this paper conducted an exploratory study of the use of adaptive learning in the flipped classroom in the Numerical Methods course. In a final examination, a positive effect size of $d=0.12$ for all students was found for flipped-with-adaptive classrooms over the flipped-without-adaptive classroom (Kaw et al., 2019). In addition, in a classroom environment inventory, there were positive effects for flipped-with-adaptive over flipped-without-adaptive-learning for all environment dimensions. Araujo et al. (2019) found that adaptive lessons in a flipped class improved test scores but without statistically significant results.

Given the limited research conducted on the use of adaptive learning in flipped classrooms and the success shown in the exploratory study (Clark and Kaw, 2020) by the authors of this paper, a fuller and more diverse investigation of the effectiveness of adaptive learning for pre-class learning in flipped classrooms is being conducted -

3) Nonlinear Equations
4) Simultaneous Linear Equations
5) Interpolation
6) Regression
7) Numerical Integration
8) Numerical Solution of ODEs

Each of the topics was broken down into chapters and are called “objectives.” by the ALP platform. There are a total of 30 objectives in the course. For example, for the topic of “Numerical Differentiation”, there are three “objectives” as follows:

1) Prerequisites to Numerical Differentiation
2) Numerical [illegible]

Figure 1. The five sections of a typical node

The introduction section includes a short overview of the topic, while the learning objectives section delineates what the student should know by the end of the node.

The video section consists of relevant lectures. For example, for the “Numerical Differentiation of Continuous Functions – First Derivative” node, the student is presented with three video lectures describing the three numerical differentiation methods: the forward–divided–difference method, backward-divided-difference method, and central-divided-difference method. These three videos had a total length of 33 minutes.

The textbook content section includes relevant sections from the textbook. The section is provided as an alternative to the lecture videos or as an additional resource.

The last section of an ALP lesson is the assessment. For this node, the question grouping for the assessment is given in Figure 2. One question is presented randomly to the student from each of the three question blocks. Two blocks have multiple-choice questions worth 1 point each, and one block has algorithmic questions worth 3 points each. To move to a node for which the attempted node is a prerequisite, a student must receive a minimum score of 59%

Figure 2. Question blocks for a typical node

3. Implementation of ALP Lessons

The adaptive lessons were tested for implementation in Spring 2021 at the first author's university. They counted for 15% of the students' final course grades. Each of the 30 objectives was presented as an assignment to students via the CANVAS learning management system. Each objective was released on a Thursday afternoon at the end of the classes for the week and due on a Tuesday afternoon 11 days later before the beginning of the classes for that week. The in-class activity was based on the work done by the deadline. Scores obtained on the objective were transferred automatically by the ALP to the CANVAS LMS an hour after the deadline. The ALP lessons remained accessible until the end of the semester for all students. The ALP lessons follow the W3C accessibility standards (W3C, 2022), while the university aids individual students through their Student Ability Services department. Accessibility standards followed in the ALP lessons include-2 (he)4 (C)Ltelityb lesson (sde)4 (nl)-2 (i)-2 o4 (s)-, -21.19 -1.1 tthe W AectsLlf (s)-(ec

1) All videos in the ALP lessons were updated to HD quality from 240p format.
2) The textbook content format was changed from an embedded PDF file to HTML to improve quality and meet web accessibility standards.

5. Case Study of Student Interactions with a Node

In this section, we ask the research question – How do students who made an A, B, and C grade in the course differ in their behavior in approaching the ALP lessons. Rather than looking at the group statistics of students who made an A, B, and C grade in the course, at this stage of the study, we look at how a typical student from each group interacted with the “Numerical Differentiation of Continuous Functions - First Derivative” node. Also, how to use the data to improve student success is beyond the scope of this paper as we are currently studying it in Spring 2022.

The node was made available on January 15, 2021, and was due to be completed by January 26, 2021, for credit towards the final course grade. A graded test that included this node was administered on February 5, 2021. The node remained available to students for review until the end of the Spring 2021 semester on May 8, 2021. Our best estimate regarding how long a student
S dat r Fervng ao04 Tw [20 (a)4 TJ( )Tj(r)3 (y 0 (w)2 (t) F)-4 (e)4 (b)]Tn(C)-3 (ont)-2 (i(nt)-2 (e)4nt)-2x15 TD[

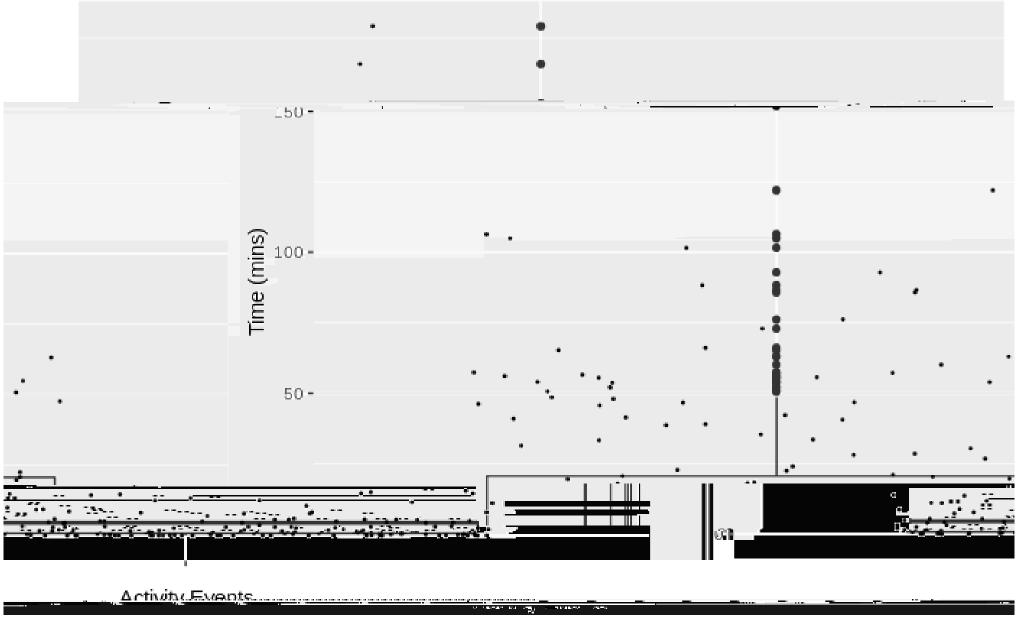

Figure 3. Distribution of activity times for the node

It is important to note that the activity times reported need to be carefully interpreted. Many of these said activities do not represent meaningful interactions between the student and the content. For example, students repeating the content in a node may quickly skip over the introduction and objectives sections and spend time on text, videos and/or questions. Disproportionately long activity times may also be recorded if a student abandons the node but does not close the browser window.

The activity time for this node is broken down by the day before the due date and is shown in Figure 4. Considering the due date of January 26, 2021, these results align with the expectation that most students access and complete the content immediately before the due date.

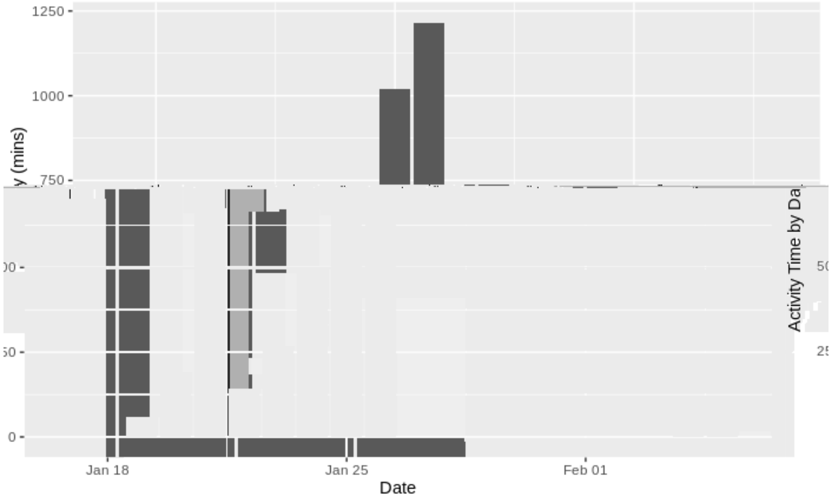

Figure 4. Activity time by date for the node.

Among the 101 students, we will focus on the activity and participation data of three students we refer to as A, B, C. The letters A, B, and C also correspond to the overall course grade they received at the end of the semester. The data collected by the ALP related to the activities of these students for this node are shown in Table 1. We have removed the fields unrelated to student activity, such as foreign keys and identifying fields, and kept only the fields directly related to the activity itself. Similarly, the participation data for these students is shown in Table 2.

Student A has one activity recorded for this node which has a duration of 47 minutes and a NormScore of 1. This record means the student completed the requirements of this node in one attempt with the maximum possible score. Within this activity, the student spent most of their time (40 minutes or 2324 seconds) on Learning Material and 7 minutes (380 seconds) on correctly answering the three required questions in the first attempt.

Table 1. Student activity data collected in the ALP

Record Id	**Student Name**	**Activity Date and Time**	**Time (mins)**	**NormResult**

C	22323	2021-01-25 18:35:00	1

Acknowledgments

This material is based upon work supported partially by the National Science Foundation under Grant Number 2013271 and the Research for Undergraduates Program in the College of Engineering at the University of South Florida (USF). The authors would like to thank Colm Howlin, Sean O’Shea, and John Healy of RealizeIT for their help during the development and implementation of the adaptive lessons. We also thank Dr. Sarah Zappe of Zappe and Cutler Educational Consulting for her feedback on the manuscript. Any opinions, findings, conclusions, or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

References

“ACT College and Career Readiness.” ACT, https://www.act.org/content/act/en/college-and-career-readiness.html (accessed April 25, 2022).

P. Araujo, W. Viana, N. Veras, E.J. Farias, J. A. Castro Filho, “Exploring Students Perceptions and Performance in Flipped Classroom Designed with Adaptive Learning Techniques: A Study in Distributed Systems Courses,” Proceedings of the SBIE 2019, 2019.

B. Birgili, F. N. Seggie, and E. Oğuz, “The trends and outcomes of flipped learning research between 2012 and 2018: A descriptive content analysis,” Journal of Computers in Education, Vol. 8, pp. 365–394, 2021.

R. Clark and A. Kaw, “Adaptive Learning in a Numerical Methods Course for Engineers: Evaluation in Blended and Flipped Classrooms,” Computer Applications in Engineering Education, Vol. 28(1), pp. 62-79, 2020.

College and University Classroom Environment Inventory, https://case.edu/ucite/sites/case.edu.ucite/files/2018-02/College-and-University-Classroom-Environment-Inventory.pdf (accessed April 25, 2022).

C. Finelli, K. Nguyen, M. DeMonbrun, M. Borrego, M. Prince, J. Husman, C. Henderson, P. Shekhar, and C. Waters, “Reducing Student Resistance to Active L- (nde)16.-2, ( )]TJ-8 (/s)2.coitnt Re AEn- (.c)-2.8 DC -3.9 (o)Pe610.04(i)il. LJln- (.

A. Kaw, S. Garapati, “Development and Assessment of Digital Audiovisual YouTube Lectures for an Engineering Course in Numerical Methods,” ASEE Computers in Education Journal, Vol. 2 (2), pp. 89-97, 2011.

A. Kaw, A. Yalcin, D. Nguyen, R. Pendyala, M. Hess, G. Lee-Thomas, G. Besterfield, J. Eison, C. Owens, “(a)1.2 (lS-3 (d))-3 (, o P)4.