

Piloting an Adaptive Learning Platform with Elementary/Middle Science Methods

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Abstract

Adaptive learning allows students to learn in customized, non-linear pathways. Students demonstrate prior knowledge and thus focus their learning on challenging content. They are continually assessed with low stakes questions allowing for identification of content mastery levels. A science methods course for preservice teachers piloted the use of adaptive learning. Design and implementation are described. Instructors need to realistically consider the time required to redesign a course in an adaptive learning system and to develop varied and numerous assessment questions. Overall, students had positive feelings toward the use of adaptive learning. Their mastery levels were not as high as anticipated by the instructor. The student outcomes on their summative assessment did not show high levels of transfer of the key content.

Keywords: Adaptive Learning, Science Methods, Pedagogy, Course Design

Introduction

Adaptive learning provides students with a customized, efficient, and effective learning path through a course's objectives and content (ELI, 2017). Adaptive learning platforms track the content that a student engages with and the level of mastery demonstrated through assessment questions. Course content is granularized and organized into nodes. Nodes consist of learning objects and embedded assessments. The results of the assessment determine recommendations for the next node attempted. Students have the flexible option, however, to self-select the order of completing nodes, so long as they have demonstrated the prerequisite knowledge or skills. (Dziuban, Moskal, & Hartman, 2016; Feldman, 2013; Howlin & Lunch, 2013).

Adaptive learning can be used as a technological tool to assist in science methods courses in engaging preservice teachers in the knowledge basis for effective teaching and learning. Topics in this elementary/middle school science methods course are typical of many such courses: the Next Generation Science Standards and 3-Dimensional learning (NGSS Lead States, 2013), conceptual change theory (Posner, Strike, Hewson, & Gertzog, 1982), components of instructional models like the 5E (Bybee, 1997) or 7E models (Eisenkraft, 2003), and basics about specific instructional strategies such as KWL charts (Ogle, 1986), Predict-Observe-Explain sequences (Haysom & Bowen, 2010), and the Claim-Support-Question strategy (Richhar, Church, & Morrison, 2011). It is important to emphasize that this

paper is NOT claiming that adaptive learning can substitute for all elements of a methods class. Sample investigations, discussions, lesson planning, and microteaching are also important elements. This paper will share the results of a pilot summer course for a science methods course for elementary/middle school teachers that used the Realizeit adaptive learning platform for approximately 50% of the course learning and activities.

Adaptive Learning

Adaptive learning provides a number of benefits (e.g., accounts for prior knowledge development, responds to current learner needs, reduces gaps in understanding, provides tools to instructors to better monitor progress) and can bring personalized learning to scale (ELI, 2017). However, “adaptive learning can be costly and time consuming to implement” (ELI, 2017, p. 2).

Instructors at Colorado Technology University (CTU) classify courses as Adaptive Learning Enriched (AL-Enriched) or All-Adaptive (Sloan & Anderson, 2018). AL-Enriched classes adaptive learning for several or most units, but multiple non-AL assignments are required and graded (such as discussion boards or projects). All-adaptive classrooms have adaptive assignments for all lessons and units. An introductory discussion board and perhaps one other non-adaptive assignment are included in the overall course grade.

Sloan and Anderson (2018) reported that students learn best when instructors use strategic, targeted instructional approaches in adaptive learning courses. AL elements are used as formative assessment and projects and discussion boards are used as summative assessment. They noted that instructors needed to link the AL content to the non-AL assignments rather than only focusing their interactions with students on the non-AL assignments. Instructors need to create a presence in their course, including in the AL platform, especially with individualized communication with students and not just group emails.

Chen et al. (2017) reported that faculty need a new mindset when designing and teaching an adaptive learning course. It has been noted that adaptive learning systems can result in non-linear approaches to instruction and remediation (ELI, 2017). Course objectives and topics has to be “granularized” and prioritized to best use the machine learning algorithms and non-linear possibilities for student pathways through the course. Specific strategies that they suggest to faculty include (1) using alternative content to allow students to find delivery methods that match their preferences, (2) adding questions with variables and conditions to allow for branching, (3) creating questions at different levels of Bloom’s taxonomy and different levels of difficulty, and (4) applying a mix of adaptive and performance-based assessments. Challenges discovered in implementing adaptive learning included (1) time-consuming design process for faculty, (2) moving from strictly summative to formative assessment, and (3) how to integrate adaptive learning components with performance-based assessments.

A pilot study at the University of Central Florida (UCF) with an adaptive General Psychology course showed that only 20% of students preferred some or substantial interaction with other students while 52% preferred little or no interaction with other students in the class (Dziuban, Moskal, Cassinsi, & Fawcett, 2016). Students were also found to report few difficulties adjusting to the Realizeit system.

Students in adaptive learning courses have been classified based upon their behavior into four categories (Dziuban, Howlin, Johnson, & Moskal, 2017). Hares begin a course immediately and race through it to completion. Tortoises make slow and steady progress on most days. Frogs log in once a week and complete content in blocks. Finally, kangaroos wait until near the end of the course but do complete it quickly. The tortoise and frog are reported to be the most common classifications found in higher education.

Designing the Adaptive Learning Elements for a Science Methods Course

The course “Teaching Science in Elementary and Middle School” was chosen as a pilot for adaptive learning at the authors’ university. While this course is mainly taught in the academic year (usually including field work in local elementary schools), it is also offered in a condensed format in the summer sessions. Rather than field work, students are required to develop an extensive unit plan demonstrating understanding of conceptual change theory and three-dimensional science education. Online, adaptive learning was used for approximately 60-70% of the course delivery of this summer course. Realizeit was chosen by the Learning Technology Center (LTC) of the author’s campus as the platform for this pilot.

The instructor mapped and designed the learning in Realizeit for this course. He began by using the principles of backward design (Wiggins & McTighe, 2005). Backward design was going to be required for the unit plan project in the course, so the instructor wanted to model its use through the course that the preservice teachers were taking.

Two enduring understandings were identified:

1. Quality science teaching involves engaging students in learning about content knowledge (Disciplinary Core Ideas), how scientists and engineers work (Scientific and Engineering Practices), and overall themes (Crosscutting Concepts).
2. Conceptual Change Models of Instruction guide teachers toward challenging students’ firmly held misconceptions/preconceptions/alternative conceptions and guiding them toward more scientific understandings of the universe.

Next, three essential questions were identified:

1. How does three dimensional science learning promote effective teaching?
2. How can instruction be planned that leads to long term scientific understandings about concepts?
3. What are strategies that help students to learn scientific content and processes?

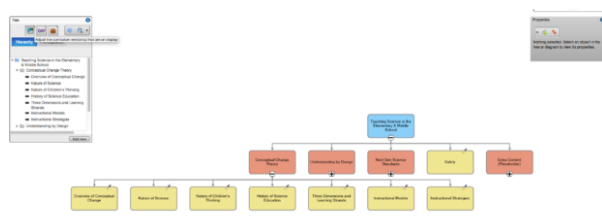
Finally, four course objectives were decided upon:

1. Students will be able to utilize backwards design for unit planning.
2. Students will be able to use elements of conceptual change theory when designing science lessons.
3. Students will be able to design a unit plan that demonstrates the ability to address all three dimensions of science learning.
4. Students will be able to show understanding of the Body of Knowledge about science teaching and learning.

Realizeit works by packing content into “nodes” which contain discrete knowledge or skills assessed by approximately 3-10 questions. The guidance given to the instructional team was that if there were more than 10 questions, the content should probably be split into smaller nodes.

The instructor and instructional design team of the LTC met to map out the nodes. The course’s main textbook *Teaching for Conceptual Understanding in Science* (Konicek-Moran & Keeley, 2015) was a main driver for the pedagogical content about conceptual change theory. Thus, one of the groupings of nodes was “Conceptual Change Theory”. One node was created for each of the eight chapters from the text that were highlighted in the course. The other main driver for the course was the Next Generation Science Standards (NGSS) (NGSS Lead States, 2013). There are three dimensions to these standards: Scientific and Engineering Practices (SEPs), Crosscutting Concepts (CCs), and Disciplinary Core Ideas (DCIs). Nodes were created in each of these areas. Finally, three nodes on backward design and one node on safety were created. A screen shot showing parts of this mapping of nodes with the Conceptual Change Theory nodes displayed is in Figure 1.

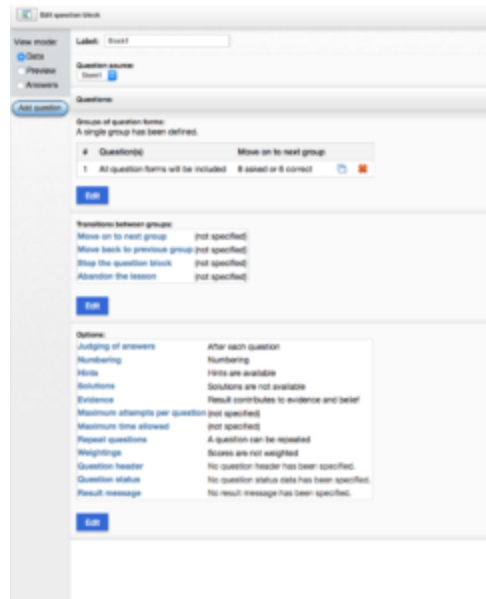
Figure 1 (Click on image to enlarge). Screen shot of curriculum node mapping in Realizeit.



After creating the map of the nodes, the instructor created text and video links for learning objects in all nodes. Videos were chosen based upon non-copyrighted, high quality materials found on the internet. Bozeman Science (Anderson, n.d.) has published a series of short videos on the various elements of the NGSS, so these were used for all of these nodes. The instructor recorded original videos welcoming students to the class and describing the mechanics of the class in order to create a local connection between the online students and the instructor; however, he did not deliver any online lectures related to the content since high quality videos already existed for this purpose. The text for the nodes came from the public domain documents on the Next Generation Science Standards (NGSS Lead States,

2013). Students were also directed to read from the rented course textbook (Konicek-Moran & Keeley, 2015) for several of the nodes. Additionally, the instructor created all of the assessment questions for the nodes. This was a large amount of work. A student worker was hired to review the questions for formatting and display. A large pool of questions is necessary since students can repeat nodes and they are selected from a random question bank. Figure 2 shows an example of how the question banks were set up for each node.

Figure 2 (Click on image to enlarge). Screenshot of question block option setting in Realizeit.



Once the nodes were finalized, the course is published into a form that can be accessed by students. Students see learning maps for each of the milestones (see Figure 3). Additionally, Figure 4 shows a screenshot of what a particular node looks like with its sequence of an introduction, learning, and assessment question blocks.

Figure 3 (Click on image to enlarge). Learning progress as viewed by students.



Figure 4 (Click on image to enlarge). Screenshot of a lesson node from Realizeit.

Learn: Matter and Its Interactions

Lesson path +

1. PS1: Matter and Its Interactions ✓
2. Learning ✓
3. PS1A Questions
4. PS1B Questions
5. PS1C Questions
6. Summary

grade level, mass and weight are not distinguished, and no attempt is made to define the unseen particles or explain the atomic-scale mechanism of evaporation and condensation.)

Middle School (5-8)

- Substances are made from different types of atoms, which combine with one another in various ways. Atoms form molecules that range in size from two to thousands of atoms.
- Each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it.
- Gases and liquids are made of molecules or inert atoms that are moving about relative to each other.
- In a liquid, the molecules are constantly in contact with others; in a gas, they are widely spaced except when they happen to collide. In a solid, atoms are closely spaced and may vibrate in position but do not change relative locations.
- Solids may be formed from molecules, or they may be extended structures with repeating subunits (e.g., crystals).
- The changes of state that occur with variations in temperature or pressure can be described and predicted using these models of matter.

This first video is about PS1A – Structure and Properties of Matter.



PS1A - Structure and Properties of Matter

PS1.B: Chemical Reactions

Primary School (K-2)

- Heating or cooling a substance may cause changes that can be observed. Sometimes these changes are reversible, and sometimes they are not.

Elementary School (3-5)

Exit

The Discussion Board was designed to be used in the course as an additional form of formative assessment. Three forums were created: one on conceptual change theory (a major course topic), one of the crosscutting concepts of the NGSS (the most philosophical elements that are often hard for teachers to conceptualize how to teach), and one on teaching practices (use of wait time, cold calling, strategies to teach science such as “Claim-Evidence-Reasoning”). Students were required to read or watch a video and then post a response. The instructor then posted follow up questions until the student demonstrated that they understood the concept. Students were given the choice about whether to complete fewer topics in a forum if they posted responses to their fellow students or to complete more topics if they were only going to respond to the instructor’s follow up questions.

Instructional Design support by LTC

The staff of the LTC provided assistance in terms of instructional design and setting up the course in Realizeit. A full time instructional designer is employed by the LTC. Because this course was being taught by a professor of teacher education, the instructional designer functioned more as a colleague with the faculty member. Coaching questions were asked to challenge the instructor to defend why the course was being structured in a particular way. This was an effective relationship between it helped the instructor to see Realizeit as a formative assessment tool. Additionally, the instructional designer helped the instructor to connect the student assessments back to the course objectives.

Student Assessment

Student learning was assessed in several ways in this pilot course: standardized assessment at the remembering/understanding level of Bloom’s Taxonomy in the adaptive learning system, discussion board prompts requiring accurate knowledge about conceptual change

theory and crosscutting concepts, and a final unit plan serving as a summative assessment.

First, the Realizeit platform tracked students' performance in two categories for each milestone: knowledge mastery and knowledge covered. Knowledge mastery measured the percentage of correct assessment questions that the student answered, with the allowance that students could go back and complete all assessments an unlimited number of times. The assessment questions did come from a random question bank, so that the students were not asked the exact same questions each time. The knowledge covered was a measure of the number of nodes/lessons that a student engaged with in each milestone. This included watching a video, reading the text, or attempted the assessment questions. The assessment questions are primarily in multiple choice format, with the possibility of different correct and incorrect answers being presented in different iterations, thus giving variety to the assessment and avoiding simple memorization. An example question about Scientific and Engineering Practice 1 is presented in the discussion section. Table 1 summarizes the results from the pilot class.

Table 1 (Click on image to enlarge)

Student Assessment Data by Adaptive Learning Milestone

Milestone	Knowledge Mastery	Knowledge Covered
Understanding by Design	90%	100%
Conceptual Change Theory	80%	99%
NGSS-SEPs	83%	94%
NGSS-CCs	88%	94%
NGSS-DCIs (PS)	82%	90%
NGSS-DCIs (ESS)	85%	91%
NGSS-DCIs(Engineering)	86%	92%
NGSS-DCIs(LS)	87%	95%

Conceptual Change Theory had the lowest knowledge mastery scores overall (80%). Since this milestone dealt with the pedagogy of misconceptions/preconceptions, conceptual change, and instructional models, it may be that these lessons were the most unfamiliar to students. The Science and Engineering Practices of the NGSS were also low (83% mastery), possibly because these eight practices may conflict in some ways with the misconception that there is a single scientific method focused on testing a hypothesis with a control group and experimental group, etc.

The adaptive learning elements of the science methods course were viewed as formative assessment in terms of course design. The student performance on their unit plan summative assessment in light of their work in Realizeit is another helpful set of assessment data to analyze. Here is the [rubric](#) used to score the unit plans. Students were rated in how their unit plan demonstrated mastery in terms of elements of backward design/understanding

by design, 3-Dimension learning, anticipating misconceptions, using an instructional model related to conceptual change, writing appropriate learning objectives, including materials and safety information, identifying important vocabulary, using instructional strategies from the text, demonstrating quality, and properly crediting references. The class average performance per category and the possible weighted score available in each category are listed in Table 2. The complete unit plan description and scoring guide are available in the appendix.

The parts of the unit plans that were most lacking (when the average points earned were less than 70% of those available) were 3-Dimensional Learning, identifying misconceptions, using a conceptual change instructional model, properly identifying objectives, and using three of the instructional strategies presented in the textbook. Those areas closely associated with the Conceptual Change Theory milestone in Realizeit were 3-Dimensional learning, identifying misconceptions, and the instructional model. It appears that students on average had difficulty applying the knowledge from the adaptive learning lessons to the unit plan. Additionally, these were topics in the lowest scored milestone, so they may not have fully understood the concepts before trying to apply them. Writing proper objectives is a lower order task (students wrote objectives such as “Students will realize” or “Students will know”) that was assessed in the Understanding by Design milestone in Realizeit (90% mastery). Nevertheless, when it came to applying this skill, the students needed work.

Table 2 (Click on image to enlarge)

Student Assessment on Unit Plans by Category

Category	Maximum Score	Average Score Earned
Understanding by Design	3	2.4
3-Dimensional Learning	2	1.3
Misconception Identification	2	1.3
Instructional Model Usage	2	1.3
Proper Objectives	2	0.9
Materials/Safety	1	0.9
Vocabulary Identified	1	0.8
Instructional Strategies	3	1.6
Quality/Detail	3	2.4
References	1	1

Student Feedback

Eight of twelve students in the pilot course completed an online survey. When asked how satisfied they were with the adaptive learning platform, 75% reported being slightly, moderately, or extremely satisfied. Only one student was slightly dissatisfied. When asked how engaging they found the adaptive learning content related to other online content in the

campus's LMS, 50% reported that it exceeded expectations, 12.5% reported that it was short of expectations, and 3 of 8 felt it equaled expectations. In terms of how useful Realizeit was as a learning aid, 1 student said it was far above average, 3 said it was moderately above average, 3 said it was average, and 1 slightly below average. When asked if they would like to use adaptive learning in a future class as a students, 1 said definitely yes and 6 students said probably yes; only one student said probably not. When asked if they would like to use it as a teacher themselves, 6 of 8 said probably yes.

Students were then asked to briefly describe their experience using Realizeit. One student in the pilot had a negative experience and said that "I struggle[d] to navigate and I feel that I'm not actually learning material." The other responses were all positive. One said "I have enjoyed it." Another elaborated by stating "My experience using Realizeit has been really good. They layer the items I need to complete for an individual module into 4 easy to understand components. As I look at each of those parts, I am detailed into the information I need to know for a strong understanding of the concept." One student commented on how adaptive learning actually encouraged him/her to learn the material: "There were some lessons that were frustrating as a struggle to become an "expert", however it helped me not only learn the material but review and remember it."

Students were then asked to describe the strengths of adaptive learning. Many focused on pacing with comments like "I enjoy that it's online and work at your own pace" or "allows students to learn at their own pace." One student focused on the cognitive side of learning with "the repetition helps engrave the information in your brain." Another student focused on the design of how curriculum content was mapped out for students in various suggested pathways: "I like how organized Realizeit is and how it paints a general picture of the modules to be completed. The additional material included is also nice to have."

Finally, students were asked to describe the weaknesses of adaptive learning. Some responses focused on engagement "I don't feel that the material is engaging to me" or "the time consumption taken in passing each lesson." Others were about the platform and course design: "the questions do not vary enough" and "it could be a little more user friendly when looking for a list of modules that fall under a larger section."

Discussion

The use of adaptive learning in a science methods course for preservice elementary/middle school teachers demonstrated many areas of promise and several areas of challenge. From an instructor's point of view, it required a large amount of time invested to create the course in a platform like Realizeit. This included granularization the content of the core into nodes and mapping them into milestones. The largest time investment was in terms of developing sufficient numbers of assessment questions so that students could go back to nodes multiple times to relearn and show higher levels of mastery. One time saving strategy was to create multiple choice questions that had multiple correct answers and additional distractors.

For instance, a question related to Science and Engineering Practice 1: Asking Questions and Defining Problems was: Which of the following is an example of the type of questions that engineering asks? There were three possible correct answers input into the system, although only one of them would be shown to students in a single attempt:

- What can be done to address a particular human need or want?
- How can the need be better specified?
- What tools and technologies are available for addressing a need?

Four possible distractors were input, but only 3 would be shown in a single attempt:

- What exists?
- What happens?
- Why does it happen?
- How does one know?

This type of question development permits many random permutations to be displayed without requiring the instructor/designer to manually construct numerous possibilities. Students appeared to “settle” for lower levels of content mastery (80%-90%) for each of the milestone than the instructor anticipated. Figure 5 shows a sample of the instructor’s view of student’s mastery levels and attempts in each milestone. With the ability to reattempt assessments unlimited numbers of times, it was anticipated that many of the students would attempt to get above 90% in most milestones to show “expert level” mastery (designated by a specific icon in the system). This anticipation was based upon how students completed quizzes on similar content in a non-adaptive learning management system for this same course that pulled questions from a random bank. Confounding factors include that this was a compact summer course offering versus a full academic year semester which may have led to time constraints for students. It is also possible that the Realizeit system’s marking of milestones with a green “mastery” icon when they reached 80% (as compared to the dark green starred icon for the 90% and above level) implied that they had reached a satisfactory level of understanding.

The area that was most concerning to the instructor was apparent lack of transfer of learning from the adaptive learning system to the summative assessment, the unit plan. Especially concerning to the instructor was the lack of use of 3-Dimensional learning (a major emphasis of the NGSS) and the use of a conceptual change instructional model.

Finally, it is important to note that overall student satisfaction with high with the use of an adaptive learning platform. Only one student in the class reported negative feelings about the system.

Figure 5 (Click on image to enlarge). Screenshot of student mastery/completion from instructor view.



The results of this pilot course have led to several conclusions by the instructor and learning technology center personnel to implement and test in further pilot studies with adaptive learning and science methods courses:

1. Emphasize the importance of Conceptual Change Theory in the Realizeit system, course design, and instructor communications with students. Highlight that the knowledge base in this section of the course is essential to the approaches to science education highlighted by the Next Generation Science Standards.
2. Changing the color codes in the Realizeit system so that the 80%-89% mastery level is not green (which may be sending a message of “good enough” mastery to students).
3. Including additional activities outside of the adaptive learning system related to the conceptual change instructional models in order to emphasize their importance. This is standard practice in the fall/spring blended versions of this course as preservice teachers write and deliver about eight lessons in a K-8 classroom in addition to face-to-face sample investigations/lessons with the university instructor. The noted lack of evidence of transfer from the adaptive learning lessons to the unit plan in the summer session may be in large part due to the fully online, compressed format of the summer session.

In summary, the instructor is excited to continue exploring the use of adaptive learning and continually improving the use of it in science methods instruction. The instructor was most pleased that the use of the system “off loaded” instructional interactions about content knowledge teaching about NGSS and pedagogy and gave the space for richer interactions with discussion boards and feedback on the unit plans allowing for revisions. These were the higher order tasks that the instructor often felt there was not as much time to interact with students when directly teaching and assessing the elements now included in the adaptive learning system.

Supplemental Files

[Final-Project-Unit-Plan-and-Rubric.pdf](#)

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