Unleashing Potential:

How Adaptive Technology Could Greatly Impact Teaching and Learning

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Introduction

Technology has been viewed as an extremely powerful component impacting not only the product, but the process of learning in the world of education. Significant research has been underway to understand how students perform best and how technology can be used to increase student engagement and ensure student success, which in turn, prepares students with readiness to enter the real world equipped with the skill sets needed to be successful. As educators, an understanding of just *how* students learn to their maximized potential is crucial. Once reaching that understanding, the idea of adapting instruction to meet the needs of our students is nothing novel. In fact, this theory can be traced back to the ideals of Socrates (U.S. Department of Education, 2013, p. 27). Recently, educational researchers have spent a significant amount of time exploring how the idea of differentiation and meeting the needs of students can be brought to the technology forefront.

 Adaptive Technology provides instruction based on the needs of an individual in ability, preferred learning styles, and strives to improve and vastly accelerate the performance of the learner. Using a web-based system to adapt instruction, students receive personalized content based on each specific learner (Siadaty & Taghiyareh, 2007, p. 1). Successful practice of such technologies have additionally explored that understanding of how the student is motivated, student prior knowledge and background, as well as limitations to the learning environment have created positive outcomes. Through adaptive technology, learners will receive a personalized approach based on all these elements creating engagement, understanding, and meaningful instruction (Walkington, 2013, p.1). This concept is contrasting a tradition style of “one-size-fits-all” instruction, instead focusing on modeling and adapting to meet needs of the learner (Limongelli, Sciarrone, Temperini, and Vaste, 2009, p.203).

 A strong focus in development of programing had been found in the mathematics and science setting as researchers and educators strongly believe that the impact of technology in this content area has extremely positive outcomes (Craig et. al, 2011, pg. 1). Research continues to advance to evaluate various systems of adaptive learning, highlighting the success of each approach and exploring ways to utilize such systems in classrooms. These approaches have been tested at various educational levels from the undergraduate classroom to elementary learners. Each approach brings about unique aspects to how adaptive learning can potentially change the way we approach meeting the needs of learners.

With triumphs in research also come barriers and uncertainty. While an ideal and potentially extremely effective approach to meeting the needs of learners, such new ideas come with further question and exploration. This literature review will explore the successful practices, as well as the limitations to such models and areas of need for further research. Adaptive technology has the potential to explode in all areas of education in the near future through the understanding of these aspects.

The Potential Impact of Adaptive Technology

Adaptive learning systems put into practice can be an extremely powerful tool individualizing, differentiating, and making learning a personalized experience. In our ever changing and progressing world of education, especially in terms of technology, we are fully cognizant that a “one-sized” fits all approach is no longer a feasible method to treat and instruct learners. Rather, using web-based programs to adapt to tasks, goals, and student interest is a practical solution to this dilemma (Siadty and Taghiyarch, 2007, pg. 1). The advancements of such systems have caught the attention of many researchers to uncover how exactly optimal learning can be achieved in such way. Many studies show that adaptive learning systems are not only more efficient, but also more effective to achieve optimal student outcomes when compared to traditional styles of teaching. Recently, it has even been concluded that adaptive learning systems are just as effective as a student receiving support from a physical human tutor (VanLehn, 201, p. 198).

Adaptive Technology is Action

Educators surely recognize that students who receive individualized instruction are engaged in more effective experiences (Desmarais and Baker, 2012, pg. 1). While the common goal of individualizing instruction is the outcome of many adaptive learning systems, how such system operates delivers such results can vary. However, it is found that adaptive systems generally follow the basis of the learner model.

Through the *learner model*, adaptive systems must use learner statistics of performance. To do so effectively, students are carefully tracked while considering the base knowledge they bring to the table as well as the topics and skills that have been mastered. Thus, this model goes far beyond simply adapting learning based on correct and incorrect responses. Constantly, the student’s thinking is being tracked as they work through the program. The system is then able to adapt the instruction, give hints, and additional practice to meet the needs of that learner (U.S. Department of Education, 2013, pg.30). Additionally, students receive immediate feedback or given hints through what is considered *Computer Aided Instruction*, or students would receive supports and hints throughout the entire *process* in an *Intelligent Tutoring System* (VanLehn, 2011, pg. 2). On top of understanding the motivational and emotional state of the learner, learner models are also able to gauge the learner’s learning style and how exactly the learner learns at optimal capacity. The learner model strives to gauge when students are frustrated, bored, and the attitudes a motivation students have towards learning (Desmarais and Baker, 2001, pg.11).

Examples from Research

One of the most well-known and researched system of the learner model are Intelligence Tutoring Systems (ITS) which have emerged in several different studies and in various different settings. ITS are designed to produce the same positive outcomes of one-on-one human tutors, thus research naturally lead to a comparison of these two approaches to reveal learning achievements (VanLahn, 2011, pg 1). At the vanguard of research on Intelligence Tutoring systems is the Open Learning Initiative at Carnegie Mellon (or, OLI) funded by a Hewlett Foundation grant. OLI explored the effectiveness of instructional, stand alone, and hybrid models through the creation online programs designed to give students feedback, information, and structure, a variety of activities to yield interactive and effective instruction (Lovett, Meyer, and Thille, 2008, pg. 2).

Emerging from the Open Learning Initiative, the Cognitive Tutor Algebra ITS was studied with 145 high school Algebra I students, a subject matter in which motivation and interest have been found to emerge. According to Kaput, this is cause for concern as algebra is “framed as a gatekeeper to higher level mathematics, with significant implications for student’s economic future” (Kaput, 2000, as cited in Walkington, 2013, pg. 933). Students were divided into two sections, in which one group of selected students received regular algebra style story problems and the other selected group received those that were personalized to their interests such as sports, music, and movies. The study found that providing these personalized experiences greatly impacted student outcome, particularly exposing complex thinking skills of writing symbolic equations from story problems, especially with students who were struggling (Walkington, 2011, pg. 941).

Utilizing some of the same core concepts of the models above, an intervention system in an after school setting was thoroughly researched using the Assessment and Learning in Knowledge Spaces (ALEKS). Sixth grade students participating in the study were split into classrooms that either used or the computer based ALEKS system or were taught by teachers. Students attended the after school program twice a week for two hours over a 25 week time period. Time was chunked into twenty minute instructional sessions followed by a twenty minute break. Outcome measures of the program consisted of results on the Tennessee Comprehensive Program (TCAP). On average, students who completed the program increased their scores from the previous testing year of below basic performance to an average level. After the one year study, researchers found that students assigned to ALEKS out performed as compared to those taught by teachers when receiving consistent exposure to the program (Craig, et al. 435-7).

Adaptive systems explored so far are not alone found upper elementary/high school environments. Recently the impact of Adaptive Response Time Based Sequence (ARTS) to consider response time to assess student mastery and strength making fluency a key contributor to learning. Two key factors lead researchers to use a time based sequence; spacing in learning and fluency. Students in the study were in the third grade and attended an online school. The system was utilized to teach student multiplication facts through a developed software; *Best Basic Math*. On average, students using the program mastered the facts in two hours. When compared to the control group, who received standard lessons, students using ARTS far out performed others. Therefore, evidence leads researchers to believe that time-based adaptive learning, like used in ARTS, has amazing potential to improve learning for elementary-aged students (Mettler, Massey, & Kellman, 2011, pg 2,532-36).

The Design of Adaptive Systems

 Learner models are developed using a unique combination of many methods to develop effective systems. Digital learning systems far exceed whether a student responds to questioning correctly or incorrectly. There is a systematic approach to understanding not only the student’s answer but to what degree of thinking is achieved. This is considered the *domain model.* This allows monitoring to go beyond a broad topic, such as solving equations, more specific areas of mastery. By targeting such specific areas of strength and weakness, the learning system is able to vary instruction, pace, supports, and then efficiently reassess the student after given supports are put into place (U.S. Department of Education, 2013, pg. 27).

 Capturing such data is a very intriguing process of various algorithms depending on the program design features. For example, the ALEKS system, as explored earlier in this review, uses a very complex model to assess student knowledge. The Markov Chain procedure is used by considering nodes in potential knowledge and the probability of the student’s current state (Desmarais and Baker, 2011, pg. 25). Another refined algorithm is an adaptive learning software from Knewton. Publishers at Knewton created such program that tags content while tracking the student’s interactions when exposed to that content. Using this algorithm, the Knewton software is able to collect thousands of data driven points of the student daily and use the data to adapt to meet needs of the different learners. Essentially, the system is “learning how student’s learn” from what kind of problems they consistently respond to best, to the time of day they are the most productive, to what types of content they learn quickly. Therefore, students are being presented with the content that best supports their learning (West et al. 2012 as cited in U.S. Department of Education, 2013, pg. 27).

Why Students Benefit from This Model

 Contrary to the beliefs many have, according to researchers, “it is not the technology that students learn from, but its role should be elucidated as a means to enhance learning”. (Siadaty and Taghiyarch, 2007, p 616). It is made clear in the previous sections of this review that technology, specifically when adaptive in nature as researched in various settings can have a positive impact on meeting individual needs. One question that remains is how exactly adapting technology is effective.

 The models explored researched what all many elements of design had in common that generated student success. Plain and simple, students learn the best when they practice. Because of the basis of these online enhanced programs, the interactive formats allow for ample practice time, as compared to a traditional learning environment. Aside from just “practice”, students are engaged in a variety of approaches from quick, to the point comprehension, to real life scenarios in which in which concepts must be applied. Because students are practicing and applying new knowledge in different situations, optimal practice is being achieved (Garfield, 1995; as cited in Lovett, Meyer, and Thille, 2008, pg. 5).

 Another crucial piece in addition to the frequent learning opportunities is the immediate feedback students need to receive. According to Anderson, Conrad, and Cobett (1989) “Immediate and targeted feedback leads to significant reductions in the time it takes students to achieve a desired level of performance” (as cited in Lovett, Meyer, and Thille, 2008 pg. 5). Various systems use feedback as yet another way to tailor student outcomes and responses. Once again, the interactive components allow students to not only know of successes, but also receive supports when struggling on said topics. Feedback is very carefully fabricated to once again be individualized to each student.

 Another key contributor to positive student outcomes lies in creating experiences that spark student interest. This is a powerful tool as interest-based opportunities have been found as an extremely positive, triggering a link to the content being taught (Reber et al., 2009, as cited in Walkington, 933). By carefully designing the learner’s environment, students are able to connect their interests to their learning, thus improving the learning process. Specifically, when working in an Intelligence Tutoring System (ITS), the relationship between interest, persistence, and attention is important to consider. How these areas relate impacts how the student uses the supports given through the system. When working together in a positive fashion, researchers found positive outcomes, like reading through an entire reading passage or faster response times.

 Finally, effective media and program design is an important consideration in program design to promote student success. One major factor in media design is student response time. When learning new information, a learner’s ability to process new information is very limited. Effective media systems work to limit the cognitive load. For example, information that is not needed to perform the task at hand is eliminated. Because of the advances in technology that adaptive systems use, the need for reduced cognitive load can be easily obtained. For example, in the OLI design one might find very short animations with narration, eliminating the need for students to form meaning between an amination and text. Instead, students are listening to learn the key concepts as the animations are in action. Such example is just one way that adaptive systems reach both auditory and visual learners, improving the outcome of the process (Lovett, Meyer, and Thille, 2008, p.6).

Impact on Educators

 For years, educators have strived to provide all learners with a personalized experience and the use of technology only enhances the educator with the opportunity to do so. As improvements in technology continually emerge in the education field, the question arise of how such technology will change the way the teacher reaches the student and how the role of the teacher has the potential to change. Aside from the benefits adaptive learning programs can have on the student, that opportunity to receive such a personalized system emerges from an educator willing and able to provide the student the opportunity.

 Many ponder, what is the most effective way to provide our students individualized support? VanLehn (2001) recently answered this question through research comparing students who went through human tutoring, computer based tutoring, or no tutoring at all to support in class instruction. Human tutoring refer to face-to-face physical tutors who either supplemented the students’ classroom instruction or in the instance of a home-schooled student, serve as a replacement to instruction. It is the understanding and belief of many that human tutors are more effective than a human tutoring approach, specifically an Intelligence Tutoring Systems (ITS) and Computer-Aided Instruction (CAI) as used throughout this study. Both the human and computer based approaches where compared to “no-tutoring” referring to student who received the same instruction as those in the tutoring without receiving any form of feedback.

 While many question the expertise of the specific human tutors used in this study, final results showed that computer based adaptive tutoring systems were just as effective as one-on-one human tutoring. However, a lot of questions remain unanswered through a reviews of studies comparing these approaches. None of the presented research reports attempts to use methods to replace the instruction of a classroom teacher with a computer based system which creates area of disconnect as human tutors are often used to replace a classroom teacher. Rather, the studies only argue that an ITS be used to support the classroom instruction. Thus, the use of these modern adaptive technologies appears to place no direct effect to the job that teacher has in the classroom. The student still need to receive the instruction that the physical classroom teacher provides, but can then support the learner through differentiation and provided individualized remedial or supportive instruction to move the student forward. As a supplement to instruction, it is clear through studies that choosing a human or computerized system has the same positive impacts (VanLehn, 2011).

The question then arises on how exactly can educators utilizing a digital learning system support instruction? Koedigner and Corbett (2006) report that further studies have shown “students taught by carefully designed systems used in combination of classroom teaching can learn faster and translate their learning into improved performance relative to students receiving conventional classroom instruction” (as cited in U.S. Department of Education, 2013, pg.28). Thus, it is important to understand that while technology has perhaps not advanced enough to replace the “job” of the teacher and the instruction that can be provided by a human being, educators can and are taking advantage of learning systems to provide students the all the benefits adaptive learning systems can provide. Administrators and teachers are able to see the strengths and weaknesses of students and the district’s curriculum using the data and immediate feedback an adaptive system provides. Teachers also have a valuable and unique opportunity to “dig into” the student’s understanding, learning, and learning styles, which, can also have direct positive effects on the classroom instructional techniques. Additionally, many teachers are faced with large-class sizes and dwindling resources. When faced with this situation, it is often very difficult for teachers to provide the rich, personalized experience that many hope and dream of. Adaptive learning systems are considered a promising supplement for teachers in this situation as they can use data provided by the adaptive software to pinpoint areas of weakness in various student groups or individual students to then then cater lessons to meet those needs.

Conclusion

 This literature review provided readers with an understanding of what adaptive learning is, the various systems developed and created by various studies, and the impact on this learning approach to both student outcomes and educators. Explored were many examples and studies that developed and implemented a customized approach to individualize the learning of students in many different settings from early elementary classrooms, to advanced high school algebra courses. Using these digital learning systems, students embark in specific, well developed, models that use the learner’s actions and response to content to cater the instruction to not only support learning but also adapt to how the student’s motivation and emotions impact their learning. Thus, educators are able to use these systems to efficiently supplement instruction and provide students with the most optimal learning experiences.

 While many positive outcomes and possibilities have been presented in this research, like most research, there are significant gaps and inconsistency leaving many questions that remain unanswered. The studies explored in this review were heavily used and researched in the math and science avenues. This is most likely due to the understanding that these subject matters require the most support and need for remedial action in a classroom setting. However, when considering a students fulfilled learning experience, other subject matters are a critical part of students learning. Many in the educational field are also wary of the up-front costs of investing in technology and software as very little considerable results for research have astronomical significant results. While these learning systems clearly have promise for the future of classroom supplemental instruction, the direct and long term effects of teaching a learning are still not clearly found or stated.

 Further, researchers must develop commonality between the different learning system approaches and the groups conducting research. The patterns and results in early research are lacking in the understanding of the ability to adapt learning for the individual. By using the data from several studies, researchers can continually build stronger designs and models of adaptive learning techniques. Collecting and analyzing data at a larger level will be a crucial element in order to make further advancements.

Despite the gaps in research and need for future, more refined research, Adaptive Learning Technology has a promising future in classrooms across the board. This innovative approach has the potential to impact the education world in remarkable ways through its technological advancements. In an education world full of pressure of teachers to meet the needs of all learners and meet various levels of accreditations and evaluation systems of student performance, the need to reach all students and provide that personal learning approach is heightened. The future of such technology has potential and will be supported by this need. The research done thus far only begins to reveal the potential for adaptive technology as an integral part of classroom design.

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