



## Teaching Innovation with Technology to Accelerate Engineering Students' Learning

### **Dr. Nasser I Alaeddine, Texas A&M University at Qatar**

Nasser I. Alaeddine is the Director of Enterprise Applications and Educational Technology at Texas A&M University at Qatar. Dr. Alaeddine served previously as an adjunct faculty at University of Phoenix and University of Maryland University College. He has more than 18 years of experience in managing, developing, and leading IT projects. Dr. Alaeddine has published a number of papers in refereed journals and conference proceedings.

### **Dr. Hamid R. Parsaei, Texas A&M University at Qatar**

Hamid R. Parsaei is a Professor of Mechanical Engineering and Director of Academic Outreach Program at Texas A&M University at Qatar. Dr. Parsaei is also a Professor of Industrial and Systems Engineering and Mechanical Engineering at Texas A&M University in College Station, Texas. He is a Fellow of the American Society for Engineering Education and a Fellow of the Institute of Industrial Engineers. Dr. Parsaei has published over 240 papers in refereed archival journals and conference proceedings. Dr. Parsaei is a registered professional engineer in Texas.

### **Prof. Konstantinos Kakosimos P.E., Texas A&M University at Qatar**

Dr. Konstantinos Kakosimos received his PhD from the Chemical Engineering Dept. of Aristotle University of Thessaloniki in 2009. He worked as Postdoctoral Research Fellow/Assistant in the same university, as visiting Research Assistant in the National Environmental Research Institute, Aarhus University Denmark and also as a Design Engineer and Environmental Consultant for a number of private firms (Hellenic Petroleum, Titan Cement Company SA, Hellenic Gold, HYETOS GP etc). In October 2012 he has been appointed Assistant Professor of Chemical Engineering in Texas A&M University at Qatar and he is also affiliated with the Mary Kay O'Connor Process Safety Center extension in Qatar. He has co-authored 3 books (among which "Fires, explosions, and toxic gas dispersions: Effects calculation and risk analysis" published by CRC Press) and more than 20 papers in international peer-reviewed journals.

### **Dr. Bing Guo, Texas A&M University at Qatar**

Dr. Bing Guo is Assistant Professor of Mechanical Engineering and a Dean's Fellow at Texas A&M University at Qatar. He teaches introductory engineering mechanics, thermal dynamics, thermal fluid sciences, and experimentation design. Dr. Guo has been involved in teaching innovation with technology since 2013, with notable products such as an app for enhanced learning of 3-D objects and a video lecture library for statics and dynamics. Guo received his bachelor's degree and doctoral degrees in Thermal Engineering from Tsinghua University.

### **Dr. Bilal Mansoor, Texas A&M Qatar**

Dr. Mansoor's focus is on integrating technology driven smart devices into engineering class rooms and graduate education. His topics of interests include smart clickers, remote sensing devices etc. His materials science research focuses on developing fundamental structure-property-processing relationships of various light-weight materials.

# Teaching Innovation with Technology to Accelerate Engineering Students' Learning

Nasser Alaeddine, Hamid Parsaei, Konstantinos Kakosimos, Bing Guo, Bilal Mansoor  
Texas A&M University at Qatar

## Abstract

The current rapid rise of mobile computing, cloud computing, and social and collaborative learning is transforming education. In particular engineering education has and will continue benefiting from this trend by leading this transformation. To stimulate the innovative use of technology for a better teaching and learning experience, the Educational Technology and Academic Affairs offices have jointly developed and introduced an annual competition to further encourage faculty and technical staff to use the digital technologies in the classrooms. This annual competition provides a collaborative opportunity to prototype and assess the impact of emerging learning technologies and facilitate educational technology innovation.

Texas A&M University Qatar campus is one of the six American university campuses established in the Education City, Doha, Qatar. Texas A&M University at Qatar campus currently offers four ABET accredited engineering degrees including Chemical, Electrical, Mechanical, and Petroleum and has proven itself as one of the leading academic institutions in the region. The major trust of Texas A&M University at Qatar is to develop, implement, and assess the most innovative use of digital technology to further assist students learning and to make the primary and supplementary course materials at students' disposal.

The educational technology steered by instructional design enables educators to achieve learning objectives and develop interactive, engaging, and personalized learning experience. Educators and instructional designers bear a responsibility to meet the demand for the use of digital technologies in academia for improved learning outcomes. This paper summarizes some of the recent projects utilizing computer and digital technologies to aide engineering students' learnings and reports on achievements observed over the past two years. These projects demonstrate that technology has a positive effect not only on learning, but also on students' motivation, on the classroom atmosphere and on teachers' willingness to experiment with new and innovative instructional approaches. In sum, teaching with technology transforms the entire learning experience.

## Introduction

Technology is becoming an integral part of our lives and its effects are no more prominent than in the lifestyles of younger generations who grew up immersed in technology. As technological innovations become pervasive, their transformative power spreads throughout society, and that includes education. The enthusiasm for emerging technologies like mobile devices, wireless networks, cloud computing, and social media stems from the tremendous opportunities they offer

to transform and enhance the learning and teaching experiences<sup>1, 2, 3</sup>. With the proliferation of educational technologies that are able to overcome the obstacles of time and space, students can get anytime-anywhere education through on-demand services. Furthermore, employing educational technology in higher education is becoming increasingly important as a means to address many of the pressures shaping the future of universities.

Several important issues arise when talking about the relationship between educational technologies and higher education. One issue that comes to the forefront is the limited success of instructional technologies in meeting the expectations of higher education institutions<sup>4</sup>. The subdued impact has been mainly attributed to the lack of willingness by faculty to implement technology-enhanced learning rather than being a result of technology deficiencies<sup>5, 6, 7</sup>. A number of studies investigating the influence of technology on teaching and learning have been conducted over the past several years and it has been shown that effective use of technology can improve student and teacher experiences<sup>8, 9</sup>. Despite the obvious benefits of instructional technologies and their potential to redefine the learning experience, adoption rates remain low.

Purchasing more technologies will not improve adoption rates. Promoting faculty change will. One of the most effective approaches to promote change is professional development programs which are often seen as vital to teacher satisfaction. If faculty members are required to integrate educational technologies into their daily practice, then they should receive technology training that is grounded in sound pedagogical practices. Technology can help pave the way for improved learning outcomes in many ways, but the full potential will only be reached if the instructor is adept at implementing technologically oriented pedagogical changes.

In this paper, we present a practical approach to motivate the use of educational technologies in higher education and report on the results of several pilot projects that were conducted in support of the proposed strategy. At the core of the strategy lies the view that faculty development is the key to the successful adoption of instructional technologies. The employed methodology utilizes a development program that is based on the notion of educational innovation through implementation. Data resulting from the pilot projects over a period of two years reveals the value of the introduced strategy in motivating faculty to come up with innovative solutions to assist engineering students meet their learning objectives.

## **Approach**

Exploring the drivers of change and planning accordingly is often seen as key to the future success or even survival of an organization. In education, the drivers of change have been thoroughly researched and documented in literature<sup>10, 11, 12</sup>. Technology is increasingly being touted as an innovative cost-effective solution to address the drivers of change in universities around the world<sup>13</sup>. Employing instructional technologies in conjunction with sound pedagogical practices could benefit both students and universities but such action will also lead to drastic changes in the educational ecosystem. Therefore, such deployments should be preceded by an extensive strategic planning process that takes into account human, technology, and pedagogy factors.

At Texas A&M University Qatar campus, leadership foresaw the evolving needs of current and future students and understood the potential of educational technologies in improving learning outcomes. As a result, the university and its leadership made the strategic decision to invest in an educational technology infrastructure that supports technology-enhanced learning and to take all necessary steps to promote technology integration in the classroom. Once the strategy was put in place, it was time for execution. The following sections introduce the process that was followed to implement and promote the technology-enhanced learning strategy.

### **Strategic Actions**

The decision to pursue technology-enhanced learning goes far beyond technology selection and integration. It involves accounting for human, pedagogical, and technological factors. Once the technology is in place, there needs to be a support structure, awareness, promotion, and training programs, and formal award and incentive packages. The goal of these steps is to make faculty aware of the new technology and its relevance, confident that there will be proper support when needed, satisfied with the outcomes, and eventually motivated to use it<sup>14</sup>.

A popular approach to long-term planning involves producing roadmaps that show where we are today, where we want to be tomorrow and how to get there. The roadmap conveys the means to connect vision, values, and objectives with strategic actions that are required to achieve those objectives. Two strategic actions were identified as necessary to address the development needs of the aforementioned factors. The first action is specific to the technology resource while the second action is all about the human element.

#### **Action One:** Develop the technology infrastructure

This stage is about establishing a technology infrastructure that aligns with the strategic objectives set by the university. The infrastructure should be adaptable and flexible to meet current needs and future expansions. To accomplish these end goals, a process of evaluation, selection, deployment, and testing was followed in collaboration with the various departments to make proper technology and vendor decisions.

#### **Action Two:** Develop the human element

There are both technical and societal reasons as to why innovative technologies have not been widely accepted<sup>14</sup>. However, faculty resistance remains the real barrier to integrating technology into the classroom. This stage is about establishing development programs to support and promote the use of educational technologies by educators. Strategies that promote faculty buy-in are at the core of any educational technology initiative.

To promote the use of technology, Academic Affairs and the Educational Technology group joined efforts to establish and sponsor an annual “Teaching Innovation with Technology” Competition. The objective of the competition is to enable education innovation through implementation with the end goal of improving learning outcomes. One of the important consequences of the competition was the development of a lifecycle for prototyping key trends and for exploring the potential of these ideas in improving teaching and learning outcomes. Important partnerships were also forged between faculty and instructional designers as a direct result of this collaborative effort.

## Educational Innovation through Implementation Lifecycle

The Educational Innovation through Implementation lifecycle is a framework that defines repeatable tasks to be performed in order to promote the use of technology by faculty members. The annual competition established to support these efforts begins by sending out a request for proposals to all faculty members. The request marks the start of the lifecycle which consists of six phases:

- **Feasibility analysis.** During this phase, all submissions in response to the request for proposals are received. All proposals go through an initial screening process to make sure they meet the acceptance criteria specified in the call. Proposals are required to clearly specify objectives, expected benefits to students, evaluation steps, success measures, and implementation plan including project deliverables. Any required hardware, software, and technical support are also expected to be highlighted in the proposal. A review committee, then, evaluates each of the submissions and selects the proposals with the most potential to improve the learning process to proceed to the next phase.
- **Design and development.** This phase is about setting up the pilot project and removing any impediments that could hinder progress. It involves all activities relating to creating learning artifacts and/or building learning objects. Tasks such as acquiring a new technology, configuring a hardware box, and developing new software tools are all considered part of this phase. Activities in this phase are collaborative in nature as they bring faculty and instructional designers together to plan and implement all requirements necessary for a successful launch of the pilot.
- **Initial implementation and assessment.** This phase marks the start of the pilot project and the beginning of the self-assessment process. Faculty get to test and prove their hypothesis regarding how they can use technology to improve the learning process. Equipped with the learning artifacts and objects created in phase two, faculty begin their technology-enhanced learning experiment in live classrooms. End of the pilot program concludes this phase. Data collected throughout the duration of the pilot is analyzed at the end of the phase to investigate the effectiveness and the value of the project in improving teaching and learning outcomes. Feedback received from students is also incorporated in the final evaluation process.
- **Share and evaluate outcomes.** Results of the self-assessments from phase three are presented by each faculty member in a final report. The reports are then used to judge the educational innovation value of the various projects. Successful projects are recognized by rewarding faculty members responsible for them. During the recognition ceremony, faculty share the results of their pilot projects and how they contributed to improving learning outcomes.
- **Multi-course implementation.** Successful projects from phase four get promoted for limited implementation in other classes. Additional data is collected from each implementation to develop a more accurate assessment of the proposed approach. If the long-term assessment happens to support the results coming out of the initial pilot project, the technique becomes a candidate for further implementations.

- Adoption and scale.** A project that proves to be effective in multi-course implementations, as evidenced by the candidate status received at the end of the long-term assessments of phase five, can become a standard educational technology offering that is available to all faculty members.

A graphical representation of the lifecycle is provided in figure 1 below.

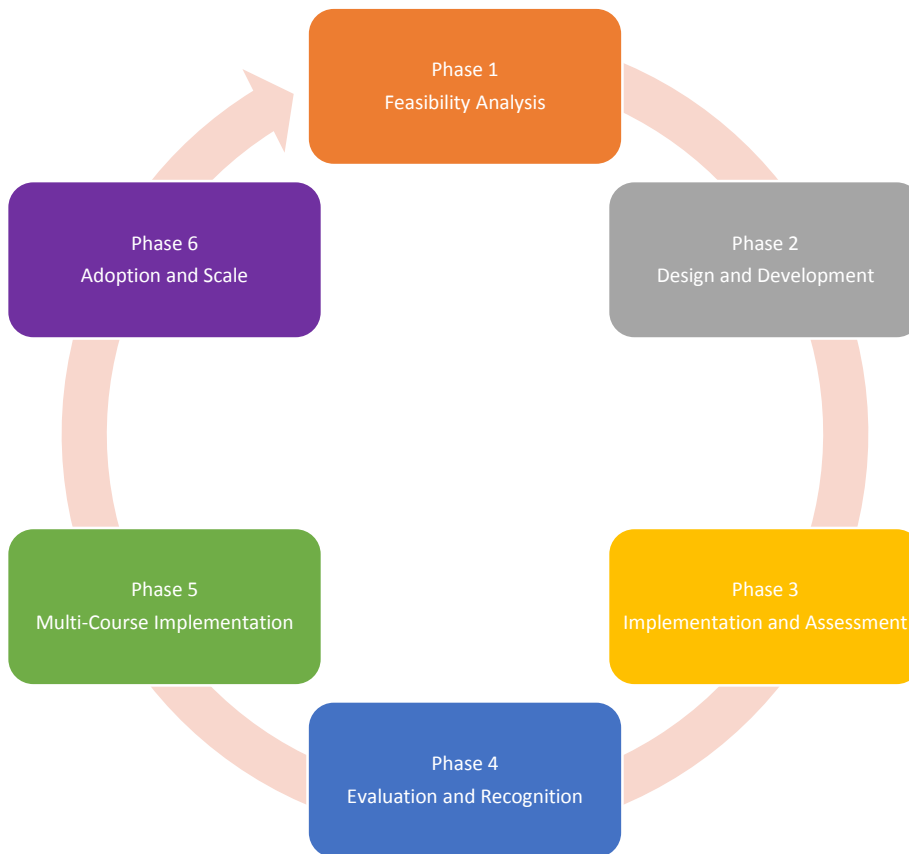


Figure 1. Education Innovation through Implementation Lifecycle

## Case Studies

A central component to the Education Innovation through Implementation lifecycle has been the engagement of faculty members in the exploration and assessment of educational technologies. This has been accomplished primarily through the Teaching Innovation with Technology Competition. This section documents these efforts and how they contributed to enhancing the learning experience. A total of six projects have been completed so far. Three projects were part of the 2013 Teaching Innovation with Technology competition while the other three came out of

the 2014 competition. The data for the later three projects is still under evaluation and will be presented at a later time. The projects are:

<b>Project Title</b>	<b>Status</b>
<b>Teaching Innovation with Technology Competition - 2013</b>	
Interactive and Collaborative Mobile Learning Platform for Engineers	Complete
Software Visualization Tool for Learning 3D Objects	Complete
Active Learning via Smart Student Response System in an Engineering Classroom	Complete
<b>Teaching Innovation with Technology Competition - 2014</b>	
Explore and develop tools for visual support of learning and training: “Google Glass”	In progress
Flipped Classroom and Interactive Engagement for Improved Student Learning in Mathematics	In progress
Flipped Classroom for Statics and Particle Dynamics course	In progress

Table 1. Competing Projects in the Teaching Innovation with Technology Competitions

## **Teaching Innovation with Technology Competition – 2013**

### **Interactive and Collaborative Mobile Learning Platform for Engineers**

Course: Fluid Operations

Objective: Develop an interactive multimedia tool that supports a bi-directional transfer of knowledge to improve the teaching and learning experience in engineering courses.

Opportunity: Provide faculty with the capability to adapt and update lecture content prior to class. This is made possible by the feedback provided by the multimedia platform when students utilize the tool to read content and solve practice questions.

#### **Project Description**

Adaptive learning is a computer-based and/or online educational method that adapts the presentation of educational material in response to student performance as evidenced by responses to questions and tasks. This project introduces a form of adaptive learning where the instructor stays in control of the adjusted content. The approach provides faculty with a unique opportunity to adjust lecture material in response to information received from the multimedia tool as a result of student interactions with the platform.

The setup for the project involved preparing lecture material for a section on “External Flows” from a chemical engineering course on Fluid operations. The material was then converted to a multimedia format using Storyline by Articulate. Adobe Flash was the format of choice due to its

extensive support. Utilizing Articulate, the multimedia file was equipped with the capability to provide feedback information with respect to student interactions with the file content. Furthermore, the multimedia content was generated with as many platform options as possible including web and iOS. Finally, the pilot platform was deployed over the learning management system a week prior to the lectures of the selected section.

Students were given access to the multimedia content and asked to go through it prior to the relevant class lectures. To ensure compliance, quizzes and exercises in the multimedia lectures were assigned to students as homework with multiple trials capability. While student went through the content and solved practice questions and quizzes, the platform gathered anonymous information about various actions including:

- Active time spent on the platform
- Number of trials and answers given for each trial and question
- Self-assessment of comprehension at each sub-section

The gathered data was then thoroughly analyzed to reveal any problematic trends such as misconceptions or misunderstandings of particular topics. The results of the analysis were then employed to adapt and update the lecture material for which the analysis was performed. For example, students participating in the pilot were asked to assess their understanding of three concepts: “drag coefficient”, “balance of forces” and “form of drag”. Student responses revealed good, fair, and poor understanding of the three concepts respectively. As a result, lectures were adapted to improve student understanding of the second and third concepts with particular focus on the third one.

#### Results and Remarks

To assess the performance of the project, three metrics were employed:

- Active time spent on the platform
- Student assessments on the ABET outcome of the “understanding external flows” topic
- An anonymous “likert” survey

Data specific to each of the metrics was collected for a group of eighteen students. The data was then studied and analyzed. Results of the analysis revealed some interesting outcomes with respect to each of the metrics.

Starting with “Active time spent on the platform”, data was collected from the multimedia platform and thoroughly analyzed. The analysis results are displayed in figure 2.



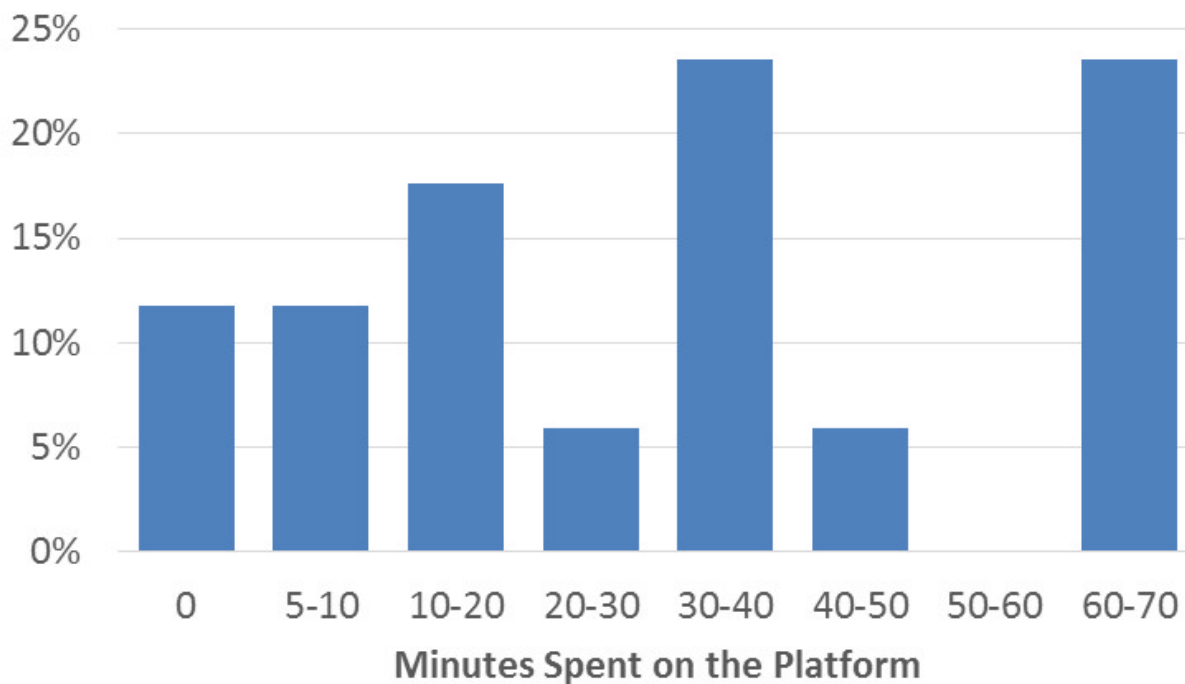


Figure 2. Active minutes spent on the platform

Even though the student sample needed around six minutes to scroll through the entire material in the pilot platform, the analysis revealed much more active use of the tool:

- On average, students spent 34 active minutes on the platform. Active time spent accounts only for the time where a student periodically used the keyboard and/or mouse. The implication here is that students in reality spent at least 180 minutes reading the material and solving the quizzes and practice questions
- 51% of the students spent more than 30 minutes while 23% spent a minimum of 60 minutes
- 17 out of the 18 students visited the platform and attempted to go through the quizzes and practice questions anywhere from 1 to 3 times

Data gathered from students via an anonymous “likert” survey verified the positive attitudes towards this approach to teaching as displayed in Figure 3.

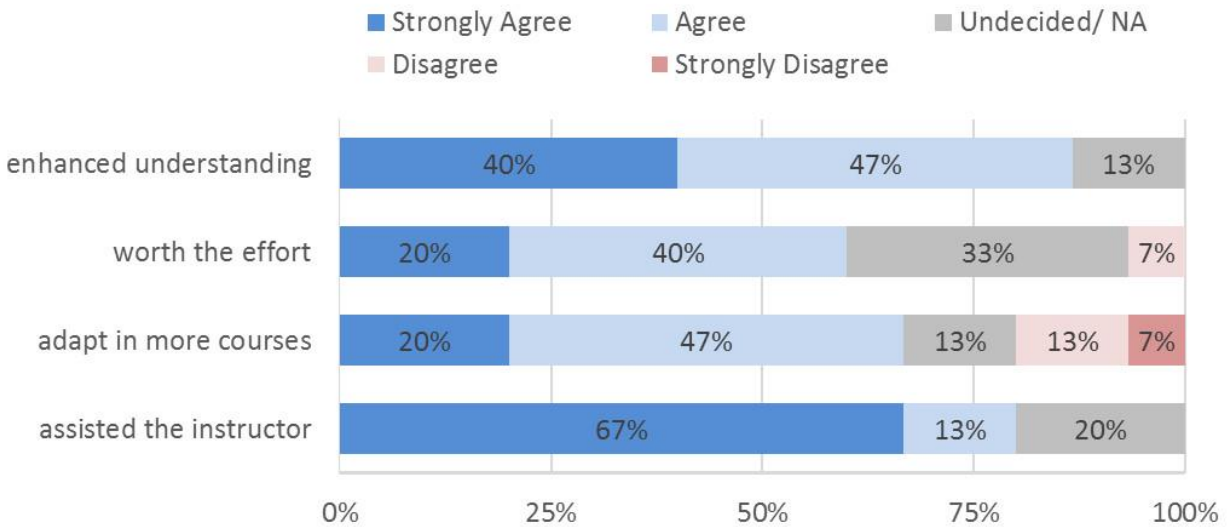


Figure 3. Results of the “likert” survey

Here are some of the highlights of the analysis

- 80% of the students agreed that the collected information actually helped the instructor to properly adapt the lectures to their needs
- 87% of the students believed that the platform enhanced their understanding as shown
- 60% of the students agreed that the development and employment of the platform was worth the effort from both sides
- 67% of the students approved of the idea of adapting the multimedia platform in other courses. 20% of the student sample did not like the idea due to concerns about how the gathered data would be used.

Finally, students assessed their understanding of the topic following the ABET outcomes approach. This outcome received around 3.9/4.0 which was the highest grade among all other ABET outcomes for this course.

### Software Visualization Tool for Learning 3D Objects

Course: Statics and Particle Dynamics

Objective: Develop a computer software visualization tool that enhances the learning experience for engineering mechanics with 3D objects.

Opportunity: Improve learning experience through 3D visualization.

### Project Description

Most people are visual learners. This project, titled VITEMIN 3D, aims at introducing 3D objects to enhance the visualization process. Towards this end, three standalone VITEMIN 3D computer applications representing three textbook problems were created for Windows 7. Each of the applications incorporated 3D views about particular topics. This enabled users to visually

inspect the topics in 3D environments. As an example, one of the applications allowed users to visually inspect quantitative vectors in a 3D coordinate system and helped them identify quantitative relations among the 3D objects.

To assess the impact of the proposed solution on learning outcomes, students from the “Statics and Particle Dynamics” class were recruited. The students were divided into two groups. Each group was presented with the task of taking a quiz specific to a 3D force vector problem. Group one was instructed to use the VITRMIN 3D application specific to the quiz problem while group two was instructed to go about taking the quiz the traditional way. Students were allowed to take the quiz online at their own pace. Both groups were asked to record the time it took each student to complete the quiz.

### **Results and remarks**

Data for the two metrics, score and time, was collected and analyzed. The data revealed the following observations:

- Students in group one scored significantly higher than students in group two. Course Grades for the “Statics and Particle Dynamics” class were inspected to ensure academic equivalence between the two groups and to eliminate the possibility of bias in the results. It was concluded that utilizing VITEMIN 3D to enhance the visualization process improved student understanding of the 3D topic and this translated into positive outcomes.
- Group one spent more time on quiz questions than group two. This could be a result of taking the time to explore the 3D visuals during quiz period.

Incorporating 3D objects to help students visualize can lead to significant benefits. And even though the project targeted problems specific to the mechanical engineering department, the concepts presented should be applicable to other engineering disciplines.

### **Active Learning via Smart Student Response System in an Engineering Classroom**

Course: Materials and Manufacturing in Design

Objective: Foster real-time active learning using smart clickers and smart clicker applications on smart devices.

Opportunity: Improve student engagement in classroom activities by embracing technologies that they like to use.

### **Project Description**

Clickers are handheld student response devices used by instructors to poll students in live classroom settings with multiple-choice questions. The instant feedback provided by clickers enables faculty to understand and possibly provide insight into students’ misconceptions. Findings from several studies involving clickers have reported increased student participation<sup>15</sup>, interaction<sup>16</sup>, engagement<sup>17</sup>, greater positive emotion<sup>18</sup>, and an increased level of preparation prior to class<sup>19</sup>. Clickers were innovative student engagement platforms and they continue to be widely used. However, the emergence of a new generation of classroom response systems that

leverage the power of the now ubiquitous smart devices, as part of the “Bring your Own Device (BYOD)” movement, is becoming more appealing to today’s tech savvy college students.

Smart devices, such as smartphones and tablets, leverage the power of mobility and the internet and box it under the hood of small packaging. Surveys and numerous studies have shown that these smart mobile devices have become an ever-present fixture in the lives of modern college students who have become accustomed to carrying them everywhere. This widespread adoption by college students offers new opportunities for supporting innovative ways of engaging learners. The core objective of this project is to foster a real-time active learning environment utilizing smart devices as clickers or smart clickers for short.

Technology by itself does not actually improve learning. Technology coupled with appropriate pedagogical practices does. Several studies involving clickers have reported similar findings<sup>20, 21</sup>. Peer instruction made popular by Harvard Physics Professor Eric Mazur<sup>22</sup> is one technique that provides several learning benefits to students and becomes even more effective when combined with the use of clickers. For the purpose of this pilot project, smart clickers were coupled with peer instruction.

A course on “Materials and Manufacturing in Design” was used as the case study for the pilot. Students registered in the course were asked to install a free clicker application on their smart devices. During a classroom session, students would be presented with various types of questions and after each question they would be provided with a short period of time to respond via the smart clicker. All scores would then be displayed. For questions relating to the lecture material, students would be split into groups to rationalize and explain their responses. The instructor employed the capabilities of the smart clicker technology to:

- Record class attendance and active participation
- Assess prerequisite knowledge
- Assess the understanding of new material and identify misconceptions
- Administer quizzes
- Provide instant feedback
- Gather anonymous feedback on teaching style

### **Results and remarks**

Student responses revealed several interesting observation with respect to the smart clicker technology and their experience with it:

- Students preferred utilizing their smart devices as clickers rather than having to deal with new dedicated clicker hardware. The majority indicated that the installation and configuration of the clicker tool was simple and the user interface was friendly and intuitive.
- Students enjoyed the idea of incorporating technology into their classrooms because it made lectures engaging, interesting, and more fun
- Students welcomed the use of smart clickers to assess their prior knowledge

- Students reported that using smart clickers in conjunction with peer instruction helped them identify areas of misconception and seek instructor insights accordingly. Having a better understanding of the instructor's expectations was another area that benefitted from this approach.
- Students favored using smart clickers to conduct future in-class assessments over paper-based quizzes. In a class survey, 70% of students indicated this preference.
- Students reported increased engagement and better interactions with the instructor. A class survey indicated that 91% of students either strongly agreed or agreed that smart clickers facilitated better real-time interactions with the instructor.
- Students indicated that the real-time assessment scoring of each question along with their individual scores enabled them to identify areas of misunderstanding. This opinion was shared by 62 percent of the students who either strongly agreed or agreed that the use of smart clickers helped them to quickly identify areas of misconception.

### **Teaching Innovation with Technology Competition – 2014**

The 2014 competition resulted in three additional entries that explored the use of technology for improved outcomes. Those entries have already been submitted and are going through the evaluation process. Only a brief introduction to each of the projects will be provided at this time as data was still being processed at the time of this writing. The three entries are:

- Explore and develop tools for visual support of learning and training: “Google Glass”
- Flipped Classroom and Interactive Engagement for Improved Student Learning in Mathematics
- Flipped Classroom for Statics and Particle Dynamics course

The objective of first entry was to investigate the use of Google class for preparing multimedia content through first-person view that could be utilized for teaching, learning, training, and evaluation of laboratory activities. The pilot required the development of the visual support tools for “Google Glass” using Android SDKs.

The second entry focused on the effective use of technology to flip the classroom in order to use interactive engagement teaching methods in three math courses. The pilot utilized several technologies including lecture capture system, online course management system, and online homework management system to do the flip. Furthermore, the project used the Calculus Concept Inventory (CCI) measure to provide an objective assessment for the gain in students' conceptual understanding that a semester of teaching produced.

The third project also focused on the flipped classroom strategy. The objective, however, was to support an existing game-style classroom activity where students are lectured the traditional way for 10-15 minutes then they are divided into two teams who are expected to compete in answering complex questions. In addition to lecture recording tools, the pilot needed an online meeting platform to enable screen sharing between the instructor and students.

## Conclusion

The wide adoption of technology in education is becoming a mandatory condition for the long term viability of educational institutions. Plans targeting this strategic objective should address human and technology factors. In higher education, resistance to integrating technology into learning has traditionally come from faculty. Strategies that address the motivational side of the human element should, therefore, become an integral part of any educational technology deployment plan. Furthermore, it is important to keep in mind that technology by itself does not actually improve learning. Technology coupled with appropriate pedagogical practices does. Educators and instructional designers bear a responsibility to promote the use of technology for improved learning outcomes. Both need to assess the pedagogical value of technology tools and explore different methods of integrating technology with instructional design processes to foster an effective use of technology in teaching and learning.

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