Flipping the Computer Engineering Gateway Courses: A Discussion of the Processes and Results

Richard Hartshorne
Educational & Human Sciences, University of Central Florida, USA
richard.hartshorne@ucf.edu

Baiyun Chen
Center for Distributed Learning, University of Central Florida, USA
baiyun.chen@ucf.edu

John Edison
Department of Electrical & Computer Engineering, University of Central Florida, USA
jedison@knights.ucf.edu

Ronald DeMara
Department of Electrical & Computer Engineering, University of Central Florida, USA
ronald.demara@ucf.edu

Abstract: Innovations to increase learning outcomes for STEM/ICT disciplines are urgently being sought. At the same time, enrollment increases of students with more varied skill backgrounds present new challenges. As enrollments increase, instructional tasks of faculty and GTAs also increase proportionally. Thus, an approach is sought to maintain and increase learning outcomes, while refocusing tasks of faculty and GTAs. EPIC addresses this need by refocusing the instructional approach, as well as optimizing *evaluation* activities using an on-campus *Evaluation and Proficiency Center* (*EPC*). Below, the results of a study examining the effectiveness of the EPIC methodology will be explored, focusing on the influence of the methodology shift and its impact on workload redistribution, student comprehension of STEM/ICT topics, and student perceptions towards STEM/ICT topics, in an effort to disseminate results from an innovative STEM/ICT pedagogical revisioning.

Introduction

As STEM/ICT educators, we seek innovations to improve the learning outcomes of students through increases in student engagement, instructional quality, academic integrity, and development of soft skills. Thus, innovations for STEM/ICT disciplines, which are scalable in both enrollment and learning quality, are urgently sought. In particular, student enrollment increases with participants with more varied backgrounds present new challenges. For instance, at the University of Central Florida (UCF), the nation's second largest university, College of Engineering & Computer Sciences (CECS) undergraduate enrollment has increased by 37.4% from 5,375 in Fall 2010 to 7,383 in Fall 2014. At UCF, a regular undergraduate engineering foundation course can have more than one hundred students. With the increasingly growing class sizes but limited instructional resources, it has become a challenge to deliver quality and equal learning opportunities to all students (Allais, 2014). Further, less-prepared and underrepresented students especially suffer from reduced interactions in large class sizes. At the same time, the assignment preparation, instruction, and grading tasks of faculty and graduate teaching assistants (GTAs) have increased proportionally. An approach is sought to maintain and increase learning outcomes, while refocusing instructional tasks.

The *EPIC Infrastructure & Curricula* was developed to translocate the optimum learning resources towards a STEM/ICT student's frame of reference at the appropriate time. The required introductory undergraduate gateway courses: *Engineering Analysis with C-Language*, *Electrical Circuits, Computer Organization*, and *Digital Logic Design* at the University of Central Florida (UCF) were adapted to the EPIC pedagogy, delivered to 1,150 students annually, assessed, and refined to:

- utilize a “flipped” instructional model including both instructor-developed and open resources to increase student engagement,
- facilitate rigorous skill demonstration and re-distribute faculty/GTA workflow through the use of both online assessments and a devoted testing facility, and online assessments in a testing facility, and
- afford students with scaffolded tutoring sessions with more knowledgeable instructors and GTAs.

Based on the Vygotskian principle of the Zone of Proximal Development (Vygotsky, 1978), and scaffolding (Bruner, 1966), learners review their evaluation results with *Content GTAs,* who are accessible for tutoring, due to their abridged homework and exam grading loads. Finally, learners requiring additional explanations can meet with the instructor to resolve any concerns mediated, as electronically-tracked task/response flows within their individualized Learner Electronic Workspace are coded and developed. Instructional tasks are shifted towards needs of personalized learning, educational outcomes, curriculum tuning, and technical topic renewal.

The Project

A primary component of the EPIC methodology is the integration of automated evaluation into the curricula. However, there are four fundamental hurdles to leveraging automated evaluation in STEM/ICT curricula. First, assessment formats are needed to deliver creative *design problems* beyond rote multiple choice. Second, lengthy engineering questions require *partial credit*. The EPIC methodology develops novel formats for design problems with partial credit which are isomorphic to pencil-and-paper based exams, but deliverable electronically. Third, STEM/ICT students require extensive guidance and student-specific coaching to learn from subtle mistakes in their designs to hone their *Proficiency*. Finally, previous exams, homework assignments, and projects are often readily available electronically in searchable repositories, compromising both evaluation integrity and proficiency. To address all of these needs, the EPIC methodology (1) engages students in an innovative model to master skills outside of class with open resources, (2) requires skill demonstration without aids, and (3) facilitates active debate of results with knowledgeable GTAs. Below, we will present the results of a study designed to the examine the effectiveness of the EPIC methodology, related to these core issues.

Our research questions include:

1. To what extent does the EPIC methodology influence student comprehension and application skills for engineering analysis and design, and computer organization concepts, among diverse and underrepresented student populations?
2. To what extent do students perceive the EPIC methodology to influence student comprehension and application skills for engineering analysis and design, and computer organization concepts?

To address these questions, we collected both qualitative and quantitative data for this mixed method research (Creswell & Clark, 2011). Quantitative data was gathered from course quizzes and exams, and pre/post student/instructor surveys to answer the above research questions. To substantiate the quantitative data, qualitative data was gathered from course observations and open-ended questions in students/instructor surveys. The quantitative and qualitative data complement each other to elicit a holistic picture of whether the EPIC framework can support student learning.

Results

In order to evaluate the effectiveness of EPIC methodology, we compared student performance in two nearly identical sections of the gateway course, *EGN 3211: Engineering Analysis and Computation*. The “traditional” setion had 66 students, while the EPIC section had 68 students enrolled. The traditional section used paper-based evaluations, while the EPIC section used computer-based evaluation with GTA assisted review. Additionally, the EPIC section consisted of students that typically perform at a lower level in the gateway engineering courses. Both sections were identical in course content, instructor, and assessment items, which was an intentional effort to determine if any measureable quantitative and qualitative improvements to student learning were realized through assessments, particularly in this initial implementation of the EPIC pedagogy. Further, it is important to note that differences in student performance measures were in addition to faculty/GTA-facing workload benefits, including, including reduced class time spent on remediation, increased efficiency in GTA time, and reduced instructor grading and improved class time efficiency realized through the utilization of auto-graded computer-based assessments, which are scheduled and completed outside of typical class meeting times.

Student Course Performance

In order to compare the efficiency of EPIC resources with traditional instruction, final course grades among students of both sections were compared (see Figure 1):

- There was a great deal of variance, with no clear trends.
- There was a significant increase in B grades and decrease in C grades in the EPIC section
- There was a significant increase in D grades in the EPIC section

Figure 1. Course grade comparison between using EPIC and traditional sections

Student Perceptions

A qualitative survey related to student perceptions of the effectiveness of the EPIC methodology was also disseminated to students. The majority agreed or strongly agreed that the EPIC-based interventions applied were beneficial for their learning. Additionally, the majority of respondents indicated: i) access to EPC increased understanding of engineering concepts (60% agree or strongly agree; 29% neutral), ii) access to EPC increased availability of assistance compared to traditional office hours (53% agree or strongly agree; 37% neutral), iii) flexible exam scheduling offered valuable convenience compared to in-class testing (93% agree or strongly agree; 4% neutral), iv) the EPC provide a quiet environment with adequate writing space compared to in-class testing (91% agree or strongly agree; 7% neutral), and v) GTA guided and self-paced access to exam results enhanced their comprehension of material (66% agree or strongly agree; 27% neutral). These preliminary results were particularly encouraging as, due to the use of EPC being optional in this initial implementation, 59% of respondents did not access the resource for test review, tutoring, or project assistance, potentially explaining the high "neutral" responses in survey questions related to these areas.

Student Benefits

Students in the EPIC section echoed a number of pedagogical benefits of rapid feedback, flexibility of scheduling, and availability of assistance. Utilizing online assessments as a tool to support increased student performance has been well documented in the literature (Angus & Young, 2009), and has been shown to illustrate an increased correlation with final course performance than unsupervised laboratory and homework assignments (Smith, 2007). For example, Lyle & Crawford (2011) reported that adding frequent online assessments in higher education courses resulted in a student performance increase of 12% in a single course. Students also cited a number of proficiency benefits in the EPIC pedagogy, including the obligation to review exam errors with GTAs. Student comments cited increased student engagement and group interaction, resulting from the ability to more explicitly explain course topics and problem solutions. An additional proficiency benefit cited was the transferability of content knowledge and associated skills. The more comprehensive and contextual understanding of course content results in increase applicability of knowledge and skills in more varied settings. Overall, results indicated that the EPIC methodology results in increased student performance, transferability of knowledge and skills, and increased student engagement.

Faculty Benefits

The resulting benefits for faculty from the utilization of electronic assessments are numerous. First, electronic assessments allow for an increased number of students to participate in a single course without an increased grading workload, resulting in an amplification in STEM/ICT degree production. Reduced grading responsibilities allows for more time to be spent improving other areas of course instruction, such as creasing more detailed/accurate/precise rubrics, reviewing student performance statistics in a more comprehensive manner in order to identify class-wide learning deficiencies, and more in-class lecture/discussion preparation time. Additionally, the EPIC methodology addresses the concern of reduced integrity and diminished effectiveness of homework problem sets created by the advent of Internet repositories, which has recently been noted as a significant and growing problem impacting student comprehension of complex material. At the same time, this results in increased understanding of the content through the implementation of more regular assessments that can be facilitated through computer-based evaluation. Further, the integration of remediation is simplified, as there is increased class time resulting from out-of-class assessments. Lastly, the reduced grading workload for instructors results in additional time to providing more specific feedback and detailed solutions for topics with high rates of misconceptions. For example, an instructor can utilize additional time to improve the course activities and resources, perhaps through the development of extra modules, to provide more comprehensive solution sets and discussion, all in an effort to improve student understanding and performance.

Conclusions

The EPIC methodology consists primarily of regularly, flexible computer-based assessments coupled with self-paced and GTA-assisted tutoring, in an effort to increase student knowledge, skills, and dispositions in gateway engineering courses. In the EPIC model, a flipped classroom approach was implemented and facilitated by rapid feedback, allowing adaptation for learners across modules and courses. It was the intent of the EPIC pedagogy to simultaneously improve student's creativity, depth of learning, and critical thinking skills through reallocation of faculty and GTA time from low impact instructional activities to more student-centric, high impact instructional activities. It is the hope of the research team that this educational approach will contribute to increased effectiveness of student understanding and performance in gateway engineering courses, and also advance the quality of STEM education, in general. Further, it is the hope that the results of this study will provide support for appropriate and effective opportunities and support services for STEM/ICT students, ultimately leading to "best practices" model to facilitate increased student engagement, achievement, and perceptions towards STEM/ICT topics, as well as workload redistribution for faculty/GTAs (from grading tasks to content tuning/renewal and individualized scaffolding practices).

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