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Improving Student Engagement and Active Learning with Embedded Automated Self-Assessment Quizzes: Case Study in Computer System Architecture Design

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Abstract. This article presents the application of integrating electronic automated self-assessment quizzes within a modern practical computer system architecture module to improve student engagement, learning and performance. Student engagement is a challenging factor within education, where students frequently disengage over module delivery and default to a passive learning style. Learner engagement and responses are crucial to the educator in order to gain insight of the learner's knowledge base, which allows the educator to react accordingly to consolidate and improve student knowledge formation. Student active learning engagement provides students an opportunity of applying their learning constructs to gain experience, self-correction, further understanding, build confidence, and develop learning constructs. Self-assessment quizzes were incorporated into the virtual learning environment for a module on computer system architecture to enable live lecture data on student learning constructs, while improving student confidence, further understanding and improved performance on the module.

Keywords: Self-Assessment Quizzes, E-Learning, Student Engagement, Enhanced Learning.

1 Introduction

Student engagement is frequently referred to as active learning within pedagogical literature [1]. Active learning is defined as some form of activity or discussion undertaken in class where the students engage with the learning process, opposed to solely passively listening to the class leader as reported by Prince [2]. Lee [3] describes active learning scenarios result in the learner utilizing higher order thinking skills to complete tasks or engage with discussions. Furthermore, the learner becomes the focus of the learning and development process, resulting in the traditional expert who disseminates information becoming more of technical guide for the active learner. The emphasis of the active learner taking control of their learning is reflected within various core pedagogical learning theories, such as experimental learning, constructivism, social learning theory, and social constructivism.

Freeman et al. [4] performed an in-depth empirical evaluation and meta-analysis of 255 studies, comparing active learning and traditional learning within Science, Technology, Engineering and Mathematical (STEM) courses. Freeman's investigation determined statistically significant advantages to active learning over traditional learning within STEM courses. The advantages reported by Freeman include significantly improving assessment performance across large and varied class sizes and even proposed the results and evidence gathered were a strong argument to warrant replacing traditional learning with active learning as the standard control variable within pedagogical investigations. Active learning techniques can consist of various approaches and techniques, such as flipped, collaborative, cooperative and problem-based learning.

This paper presents automated Self-Assessment Quizzes (SAQ) embedded into virtual learning environments to promote student engagement, active learning, formative feedback and student performance within a computing system architecture case study. The computing system architecture module is a final year undergraduate degree module and involves modern and practical embedded computing architecture, internet-of-things infrastructure and digital systems. The module lab activities are enhanced with the implementation of current computer architecture systems on FPGA devices. The MIPSfpga platform from Imagination Technologies [5] is utilized with Xilinx Nexys4 DDR FPGA platforms.

2 Digital Technologies for Active Learning

Active learning techniques within class times involve various tasks for developing higher order thinking, where authors such as DeLozier and Rhodes [6] highlight active learning techniques suitable for engaged classroom can involve: audience response, discussion-based open-ended questions, quizzes, group activities and presentations. The digital native generation of current student learners have been demonstrated to be significantly more responsive to digital technology use within classroom environments as discussed by Margaryan et al. [7]. This naturally alludes to an argument for considering digital technology for delivering the active learning component within learning activities.

Tamin et al. [8] investigated the range and impact of digital technology within the classroom and demonstrated the greatest level of improvement with student engagement and performance when the technology was used to support student cognition, opposed to using technology to present information. As observed by Coca and Sliško [9], digital technologies promote active learning of classroom learners through introducing two-way interactions into the curriculum. Furthermore, in a more recent investigation, Glazewski [10] evaluated the current need of digital technology for pedagogical teaching and learning, where it can be observed that technology should provide a platform for the educator to captivate and interact discussions with the students to achieve the desired learning outcomes. Murphy and Sharma [11] recognized two main pedagogical premises for achieving interactive classrooms known as dialogic and active learning constructs, where dialogic and active learning constructs support traditional and active learning methods. Furthermore, this interactive digital learning promoted by Murphy and Sharma can provide interactive lectures to stimulate active engagement from the classroom and provide instant feedback for both, the learner and educator. Thai et al. [12] describe that feedback component for interactive lectures should be designed to promote reflective learning on the material presented and allows the lecturer to become proactive and accommodate the classes understanding as required. Furthermore, this feedback component can be learner centered and provide effective interactive lectures. The questions presented would be required to be specifically designed to promote the relevant and focused learning outcomes and potentially lead to discussion within the classroom and achieve suitable learning efficacies, such as social constructivism [13]. Additionally, the use of interactive lectures has led to reports of improved student attendance, engagement and class enjoyment with students as presented by Gannon-Leary et al. [14]. A significant factor presented by Simpson and Oliver [15] is student anonymity, where students contributing to class questions are concerned over their social status and how they are perceived. Gannon-Leary et al. [14] and Simpson and Oliver [15] both presented significance to the design of questions, which should be undertaken to promote discussions within the classroom. An interactive learning framework presented by Saravanie and Clayton [16] directly addresses interactive lectures through technology, detailing its use to enable learning, engaging with students and empowering the teacher. While a more comprehensive literature review on current technological solutions for promoting engaged learning communities has been undertaken by Fonseca and García-Peñalvo [17]. In summary, technology could be utilized to provide an interactive tool to students within a classroom and provide bi-directional feedback to the students and teacher. This interactive tool could take the format of digital polls, self-assessment quizzes, group discussion and feedback delivered, while supporting various learning frameworks.

3 Methodology

There are various digital software suites and options for providing digital SAQ for active learning and interaction during classes. The proposed SAQ framework presented provides learning resources for the learner to review, which results in student learning occurring. The learning resources consist of various activities, including lectures, videos, articles, flipped learning and lab work. The learner will undertake SAQ at scheduled points during learning delivery, where the SAQ will provide automated formative feedback specific to the learner’s response to enhance individual learning feedback. Additionally, the SAQ system will generate and provide real-time data on student engagement and performance during delivery. This allows the teacher to facilitate and enhance the learner’s knowledge constructs. The teacher with the SAQ real-time data can provide additional consolidated material as required or go over specific content based on the individual and group learning needs. The proposed SAQ framework is presented in Fig. 1.

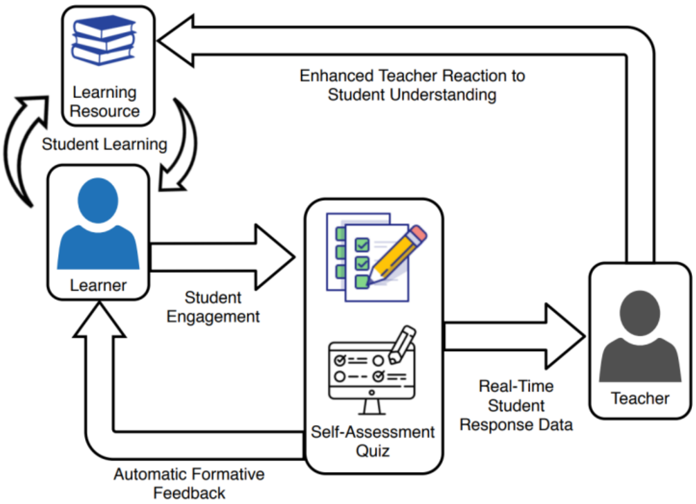


Fig. 1. Proposed SAQ framework for enhanced student engagement and learning

The proposed SAQ framework is implemented in Group 1 of 20 students $n = 20$ and the student engagement and performance metrics are evaluated over a 12-week Trimester delivery mode. Additionally, Group 1 is compared to a control group; Group 2, consisting of 13 students $n = 13$. Group 2 is the previous module cohort of students who completed the module without the SAQ framework implementation. Students were consulted as integral components to developing a SAQ system to meet their specific criteria.

The proposed SAQ question types developed within the framework would focus on application, analysis and evaluation of learning constructs and not on factual recall. The questions would require students to apply the learning constructs covered within the learning environment to successfully answer. The design of the questions allowed the learning topic to be explored in various aspects, including; applying mathematical equations to different scenarios and comprehensive higher-level exploration of concepts. Some exploration questions would require group discussion to facilitate further active learning construct development reflective of a social constructivism [13] and human social learning agency environment [18]. The proposed SAQ would evaluate student metrics for student engagement, learning and performance. Student engagement would be determined by the number of student answers submitted in comparison to the students in attendance. Student learning would be measurable from the students in terms of correct answers within the SAQ and their overall exam performance. The performance of the student groups would be measurable in terms of ability to demonstrate and apply learning constructs as measured in correct SAQ response and exam grade.

4 Student Consultation

Students within the study were consulted during the design process, where they stated they would prefer a non-virtual learning environment integrated SAQ tool for engaging with. The reason provided for not wanting the SAQ system to be entirely integrated was due to concerns over the virtual learning environment recording their performance against their user and the students requested an option to maintain anonymous interaction. Google Forms was selected for implementing within the SAQ for students primarily due to the lack of compulsory student ID user record and running on a service not entirely integrated within the virtual learning environment. Additionally, Google Forms provides significant flexibility for technical users who can program interactions and automated actions while providing confidence in students' anonymity. The students were provided a demonstration of the SAQ operating within Google Forms to demonstrate the beneficial improvement to their e-learning environment. Students were asked two questions related to the perceived help and confidence achieved from undertaking the example:

1. "*To what degree do you think it would help you?*"
2. "*To what degree do you think it would improve your confidence in ability to understand and answer module content?*"

The student question responses are presented in Fig. 2 and 3 (where students = *n*).

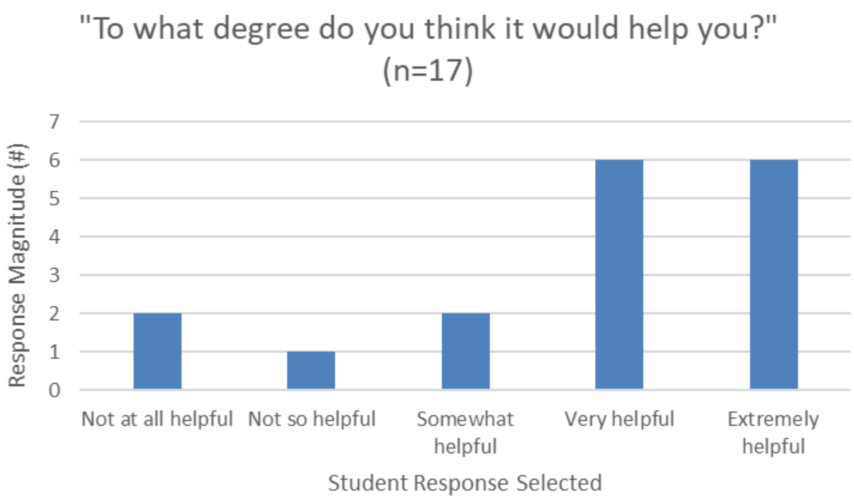


Fig. 2. Student opinion on degree of digital interactive tasks benefit.

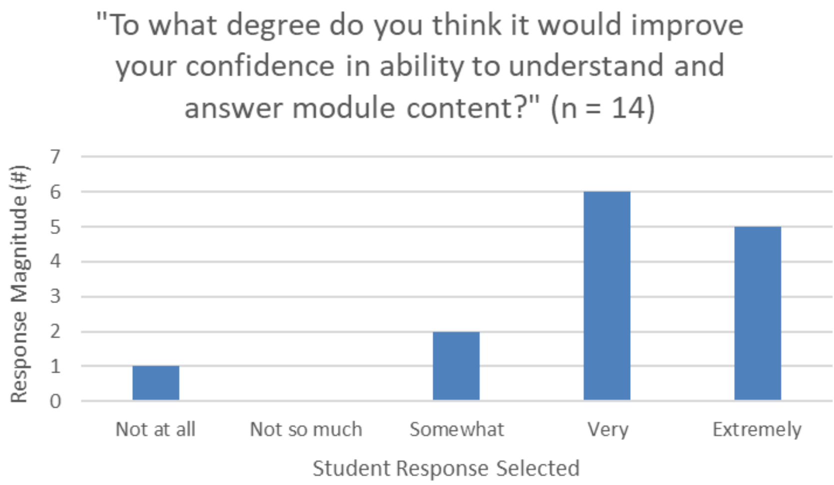


Fig. 3. Student opinion on degree of digital interactive tasks confidence benefit.

The student consultation had 17 students *n* = 17 in attendance (3 students out of the cohort did not attend), where all 17 students answered the initial poll and 3 students dropped off in responses for the second poll. The significant majority of responses were positive to the proposed SAQ e-learning enhancement, where the students recognized it would be beneficial to their module undertaking and confidence in their ability to answer module content. 82% (*n = 17*) of students attended confirmed the SAQ would help them during the module, where 93% (*n = 14*) confirmed it would improve their confidence in their ability to answer module content questions.

5 Automated Self-Assessment Quizzes Implementation

Digital SAQ were created to provide different levels of engagement, where some would be knowledge checks with yes/no answers, while other points would require the students to undertake some work, such as working through some mathematics and selecting the correct answer. Google Forms were created to accept anonymous data only. A solution template was used in Google Forms, where the students would receive customized feedback for each response. Wrong responses were configured to produce constructive feedback directing the students to the correct source of information and encourage them to try again. An example of a Google Form SAQ is shown in Fig. 4, where the learner customized specific feedback is demonstrated in Fig. 5.

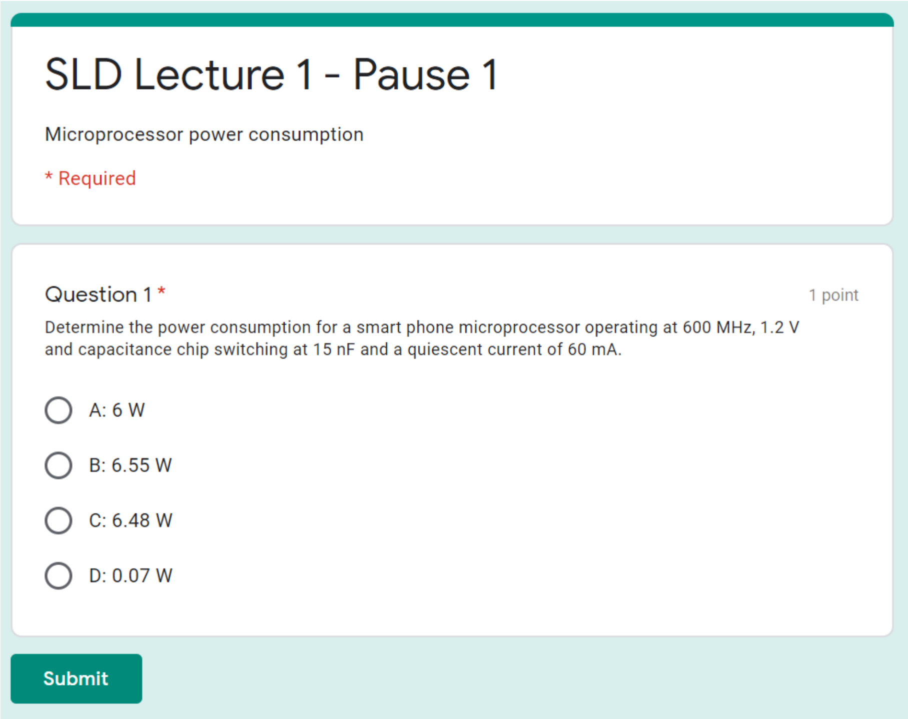


Fig. 4. Example Google Form poll question and multiple-choice answers.

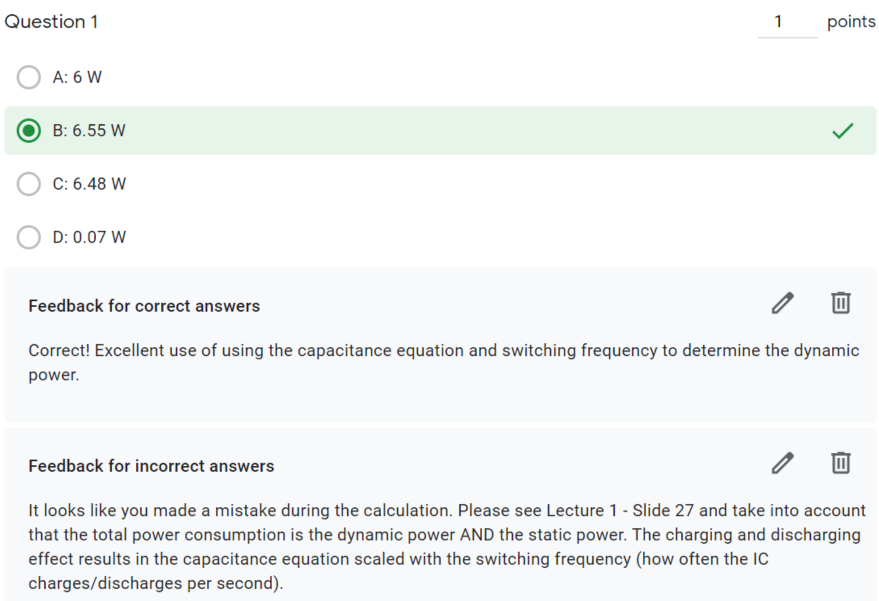


Fig. 5. Example Google Form poll customized feedback to student response.

The SAQ during live synchronous learning activities were often delivered by shortened URLs presented on slides for specific learning progression points, where an example is shown Fig. 6. Asynchronous or online learning activities SAQ were embedded within the virtual learning environment for students to access, where an example is shown in Fig. 7.

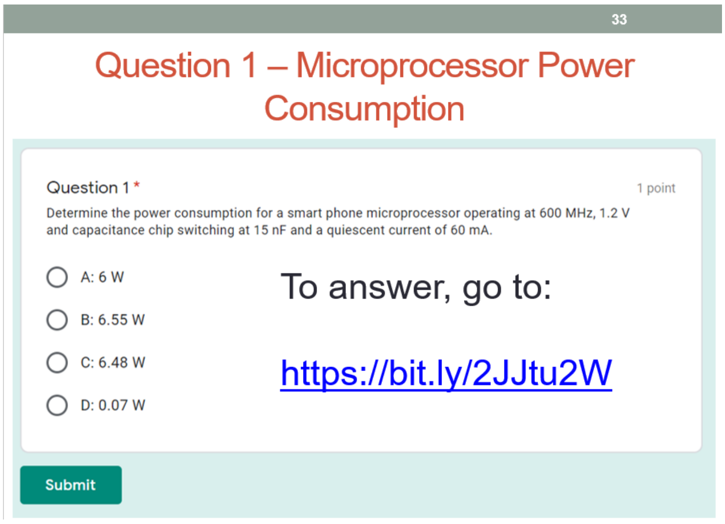


Fig. 6. Example slide with question, possible answers and shortened URL.

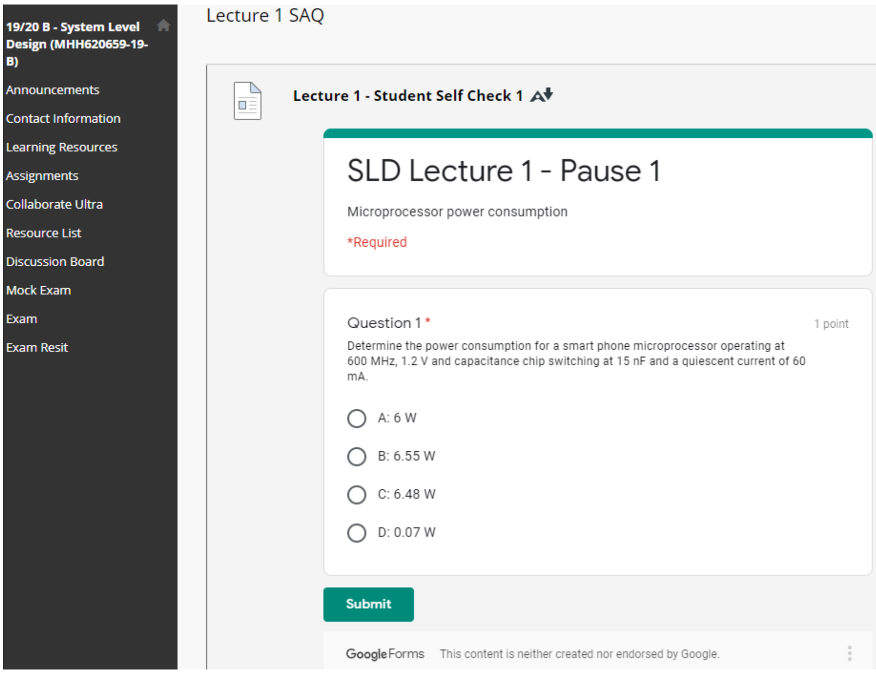
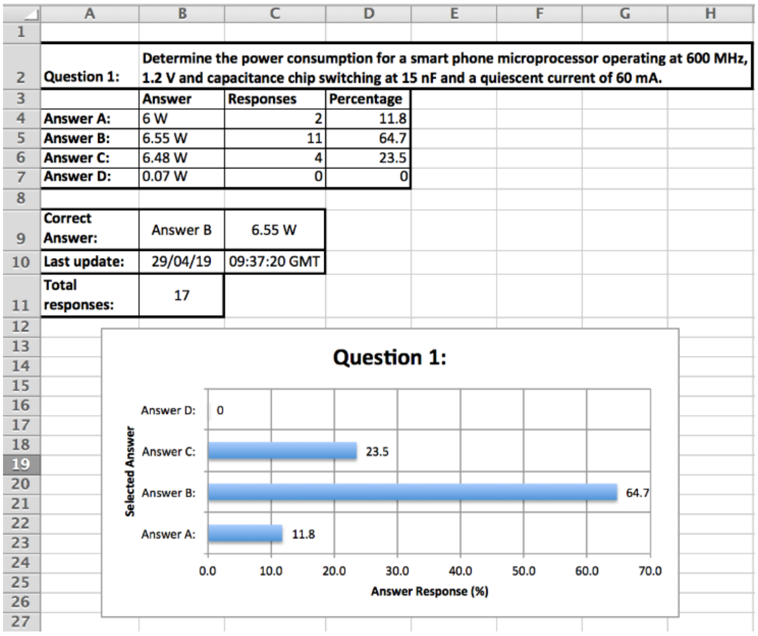


Fig. 7. Example virtual learning environment embedded SAQ.

A script was created to push updates from student responses to a Google Sheet as shown in Fig. 8 to allow real-time analytics of student interaction. The Google Sheet contains student engagement details, including total number of student responses, full student choice breakdown along with time data of last update, and number of students who were correct.



Question 1:	Determine the power consumption for a smart phone microprocessor operating at 600 MHz, 1.2 V and capacitance chip switching at 15 nF and a quiescent current of 60 mA.		
	Answer	Responses	Percentage
Answer A:	6 W	2	11.8
Answer B:	6.55 W	11	64.7
Answer C:	6.48 W	4	23.5
Answer D:	0.07 W	0	0
Correct Answer:	Answer B	6.55 W	
Last update:	29/04/19	09:37:20 GMT	
Total responses:	17		

Fig. 8. Example real-time data from student responses.

To promote active engagement within classes; the digital SAQ would take place at natural points in class to provide a break to students and to promote a discussion forum to discuss the content and formulate higher order of understanding out with their zone of proximal development if needed. SAQ were also provided weekly to allow students to reflect on their week of learning activities. All response data was reviewed during live synchronous sessions and weekly for online and asynchronous sessions. This allowed the teacher an overview of student learning and to react accordingly with material or explanations to help enhance the learner's knowledge.

6 Active Student Engagement and Performance

Student engagement with the digital SAQ started low for the initial 2 weeks, then increased to the majority of class being involved and responding to the Google Form SAQ system as demonstrated in Fig 9. The initial average response rate for week 1 was 27%, which increased to 86% by week 3. From week 3 onwards the average response rate stayed within the bounds of 78% to 100%, where there were two weeks (weeks 8 and 11) of 100% response rates. The SAQs demonstrated the student cohort engagement improved over the module delivery. Additionally, observed student engagement within discussion followed a similar trend, where after two weeks, the majority of class were actively engaging and discussing learning tasks, where in the final weeks of delivery students were self-leading discussion points from SAQs.

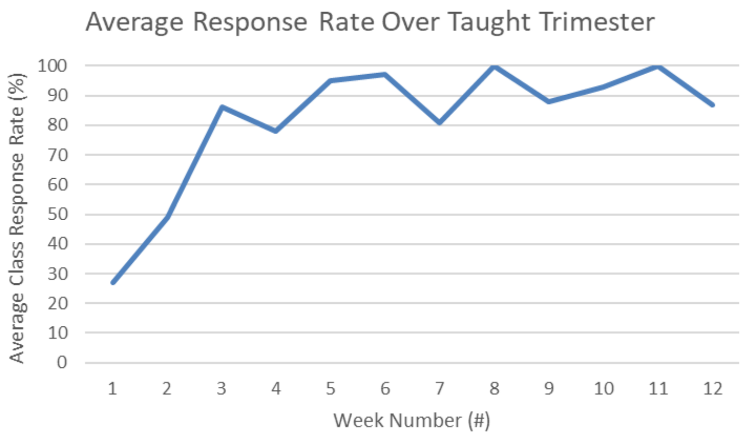


Fig. 9. Average student response rate.

Furthermore, the percentage of correct responses collected from students for these class activities initially started low, where from week 5 onwards the majority of responses were correct as shown in Fig. 10, demonstrating improved active learning. The initial two weeks of module delivery had average correct responses below 40%, where weeks 3 through 5 saw a fluctuation during increase to 88% average correct responses. From week 5 onwards the SAQs responses stayed within the bounds of 84% to 100% for average correct response rate. The student cohort only demonstrated 100% correct response rate in week 9.

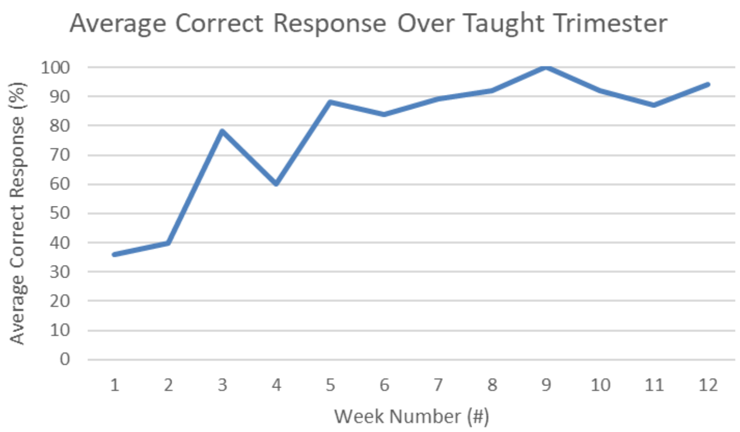
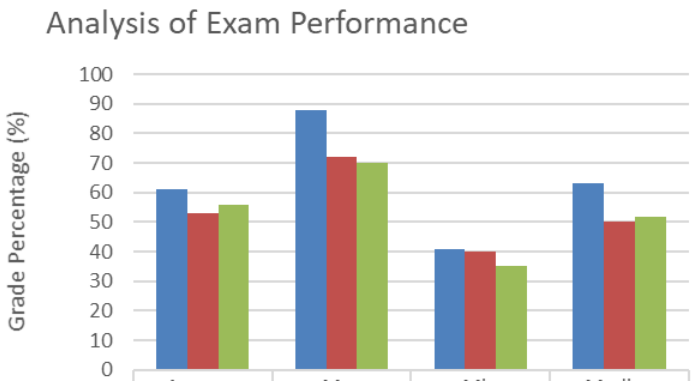


Fig 10. Average student correct response rate.

The Group 1 cohort for Computer System Architecture (CSA) module with the SAQ system was compared with the Group 2 CSA student cohort without the SAQ system. Additionally, a comparable Other Module (OM) without the SAQ system undertaken by Group 1 within the same academic year is presented to provide a baseline performance for Group 1. The various cohort exam performance metrics and grade distribution are presented in Fig. 11 and 12. Percentages were used to represent the students due to the inequal cohort number.



	Average	Max	Min	Median
Group 1 - CSA + SAQ (n = 20)	61	88	41	63
Group 2 - CSA (n = 13)	53	72	40	50
Group 1 - OM (n = 20)	56	70	35	52

Fig. 11. Exam comparison performance metrics.

Group 1 with the SAQ performed objectively better than Group 2 for CSA, where the average, maximum, minimum and median obtained exam grades demonstrated improvements of 8%, 16%, 1% and 13% respectively. It should be noted that no student failed the exam in either cohort year for CSA. Additionally, the baseline of Group 1's performance within the OM is comparable to Group 2's performance within CSA, demonstrating a maximum 5% difference for the minimum grade, while average, maximum and median values are within 3% deviation. It should be noted that one student from Group 1 failed the OM. Hence the objective performance metrics of Group 1 has improved with the SAQ system in comparison to Group 2 and Group 1's OM baseline performance.

	<40	40-49	50-59	60-69	70-79	80-89	90-100
Group 1 - CSA + SAQ (n = 20)	0	25	20	30	15	10	0
Group 2 - CSA (n = 13)	0	31	38	23	8	0	0
Group 1 - OM (n = 20)	4	36	36	20	4	0	0

Grade Distribution (%)

Fig. 12. Exam student performance distribution.

The distribution of student achieved exam grades for Group 1 undertaking CSA with the SAQ demonstrated an improvement in comparison to Group 2. For CSA, 45% of Group 1 students with SAQ achieved <60% on the exam, while 69% of Group 2 without the SAQ achieved <60% on the exam. Group 1 undertaking CSA with the SAQ system demonstrated a 24% improvement in students achieving over 60% in the exam. Group 1 in comparison to Group 2 for CSA demonstrated improvements of 7%, 7% and 10% for student achieved grades in the bands of 60-69%, 70-79% and 80-89% respectively. Additionally, more students within Group 1 achieved higher grades for CSA with the SAQ system than the OM. 76% of Group 1 students achieved <60% for OM, where 45% of Group 1 students with the SAQ in CSA achieved <60%, demonstrating an improvement difference of 31%. The distribution of student achieved exam grades demonstrated an improvement with the SAQ system where more students were obtaining better grades within Group 1, however there is still a large number of students performing poorly within the 40 – 49% band. It is noted the poor performers of Group 1 were the disengaged students with attendance issues noted towards the end of the module delivery.

The objective signifiers presented and discussed, demonstrates the CSA module enhanced with SAQ e-learning implemented were beneficial to student performance within the module, however more data samples are required due to the limited testing in student numbers.

7 Conclusion

The SAQ system designed and implemented provided automated feedback to the learner, while providing real-time data metrics for the educator to react and enhance learning constructs. The SAQ system utilized Google Forms to retain anonymous interaction for students on the CSA module, while promoting active student engagement with the learning material. Active student engagement with the SAQ system was above 76% average class responses for 66.7% of CSA module week delivery. As noted during the results evaluation, the metrics displayed signify the SAQ e-learning enhancements were a success, where more data would be required to ascertain any level of statistical significance. Students were noted to find the Google Forms SAQ very constructive, which led many students to undertake and retake the quiz multiple times at later dates for student self-revision. The implemented SAQ demonstrated average and maximum grade improvements of 8% and 16% respectively. The SAQ student cohort obtained a 24% improvement of students achieving more than 60% in their final exam. However, there were still a large number of students (25%) within the 40-49% band. From observations, these students were the less engaged students over module delivery and achieved grades within the same band on the OM baseline performance. Verbal feedback was observed from the lower performing students stating the SAQ was time consuming. Students were surveyed at the end of their module and 100% of students stated to have found the SAQ to stimulate their active learning during the module, where 94% agreed to finding the SAQ was beneficial to their learning and 88% found the SAQ improved their confidence within the module.

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