The Use of a Concept Inventory to Enhance Student Success

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1. Introduction

The number of students successfully completing their engineering degrees, at Stellenbosch University, within the minimum required time has decreased at my faculty, especially among Black, Coloured, and Indian (BCI) students from disadvantaged backgrounds. In general, student success refers to the achievement of academic, personal, and professional goals. However, according to [1], a more comprehensive definition of student success should encompass various dimensions, including academic, social, emotional, and career development.

For this work, the former definition of student success is implied. Therefore, student success can be measured by a variety of factors, including grades, graduation rates, and employment rates. The faculty has identified ”bottleneck” modules with higher failure rates, and one of the key challenges is the inability of students to apply engineering science knowledge from one module to another.

The use of a concept inventory amongst the multiple intervention that have been implemented to enhance student success at the faculty has shown remarkable results as reported in [2]. The concept inventory consisted of multiple-choice questions that assess students' conceptual understanding in the module. Alternatively to [2], a concept inventory can serve as a diagnostic tool to assist in instructional planning and evaluate the effectiveness of learning and instruction such as in [3–5].

This project focuses on developing a concept inventory as a diagnostic and another as a scaffolding tool to assist students in applying engineering science concepts in a final-year Electronics module. The diagnostic concept inventory covers key concepts from prerequisite modules (systems and signals) and is used to assist in lecture planning. The scaffolding tool will be made available online such that students can utilize it whenever necessary.

The project aligns with the University Capacity Development Grant (UCDG). Its alignment with the UCDG further underscores its significance in addressing transformation imperatives and fostering student success within the university system. As a change management project, this initiative involved various stakeholders, ensuring its potential for wider adoption and long-term sustainability. The stakeholders, such as faculty members, students, and institutional leaders, increases the likelihood of the project being embraced and continued by others.

It also aligns with the institution's Teaching and Learning policy, specifically in delivering graduates who reflect the university's desired attributes. The project contributes to institutional policies by providing material development for student development and improving the quality of teaching and learning in undergraduate studies.

The changes that were sought through this project included improved and identifiable application of engineering science concepts by students, and the ability of lecturers to identify and address misconceptions effectively. These changes are expected to lead to improved throughput rates and higher-quality graduates. By incorporating social justice principles, the project aims to raise awareness among engineering students about the consequences of their decisions and promote environmental consciousness.

2 Process

The development of a concept inventory necessitates collaboration with lecturers teaching prerequisite modules, such as systems and signals. Their input, including module guides and past question papers, informs the creation of effective multiple-choice questions that probe misconceptions. This project is part of a larger community of practice within the faculty, focused on developing multiple concept inventories. By leveraging the expertise of educators and engaging in an iterative process, the project ensures the accuracy and relevance of the concept inventories in assessing student understanding in engineering science.

(a) Diagnostic concept inventory

Multiple concept inventories have been developed in the field of electrical engineering, as demonstrated by studies such as [4, 6, 7],etc. The work done by Wage *et al.,* in [8], on the development of a concept inventory for systems and signals has been particularly valuable. This concept inventory focuses on assessing conceptual understanding rather than computational skills and includes both single concept and multiple concept questions. The questions presented in [8] are sufficient and are used to effectively identify common misconceptions, that is, they are used to create a diagnostic concept inventory covering continuous and discrete time signals. The inventory was enhanced with a question on circuit analysis, specifically focusing on power electronics, to make it more relevant to the final-year module.

The administration of the concept inventory took place during the second week of the semester as a timed, invigilated sit-down test. This approach aimed to provide an early assessment of students' conceptual understanding and identify any misconceptions that could be addressed throughout the course.

(b) Scaffolding inventory Based on the results of the diagnostic concept inventory test, a second concept inventory was developed to enhance students' understanding of waveform visualization in the context of circuit analysis. The author, drawing upon their expertise in power electronics, designed twelve multiple-choice questions that focused on relevant circuit scenarios. Eight of the questions serve as a diagnostic tool to identify misconceptions and gaps in knowledge related to waveform visualization in power electronics circuits. Four of the questions aim to foster critical thinking and reflection, encouraging students to consider the social implications and ethical dimensions of power electronic engineers when implementing solutions in society. By incorporating feedback from colleagues and aligning the questions with established learning outcomes and course objectives, the concept inventory was designed to promote meaningful learning experiences.

3. Results

Figure 1 presents a diagnostic test question that assesses student misconceptions about filtering. It displays four sinusoidal plots and asks students to identify the sinusoid with the highest frequency, with distractors probing potential confusion between high frequency, high amplitude, and large period.

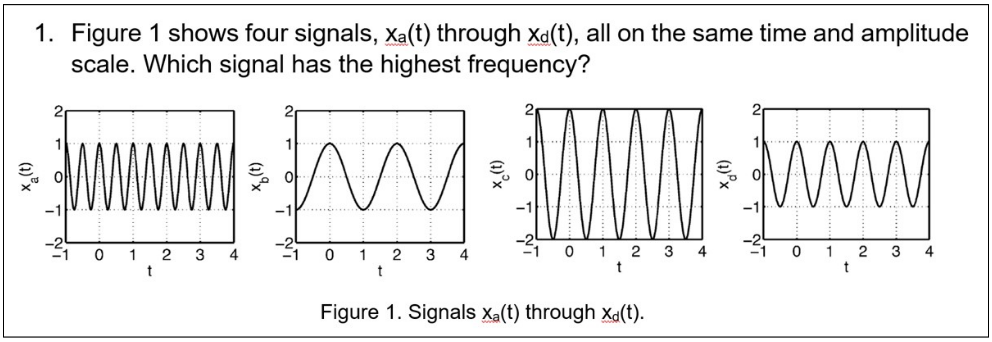

Figure 1

The concept inventory results are presented in Figure 2. The figure reveals that approximately 95 % of the students correctly answered the first question. However, less than 50 % of the students provided correct responses for questions 3 and 7. Question 7 specifically examined the students' understanding of time-frequency relationships. They were given a time signal plot and its corresponding Fourier transform magnitude for one narrowband pulse. Then, they were presented with the time signal plot for a second narrowband pulse of higher frequency and asked to identify the plot representing the Fourier transform magnitude for the higher frequency pulse. The results indicate that some students exhibited confusion regarding the relationship between time and frequency domain signal representations. This confusion hinders their ability to integrate multiple concepts necessary for solving complex problems. Students were then paired in groups to promote collaborative learning during tutorials, following Vygotsky's social learning theory. Tutors were availed to assist and students were encouraged to engage in discussions and explain concepts to each other. This approach aimed to facilitate peer-to-peer learning, enabling students to collectively address misconceptions and enhance their understanding. While the initial response from students was positive, some of them encountered difficulties as they began utilizing tutorial time primarily for individual study purposes. Impressionistic results demonstrating improvements for BCI students are shown in Figure 3.

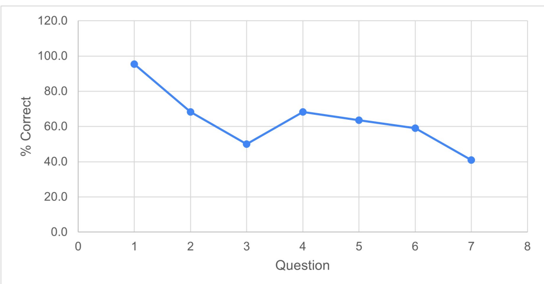

Figure 2: Diagnostic concept inventory students results

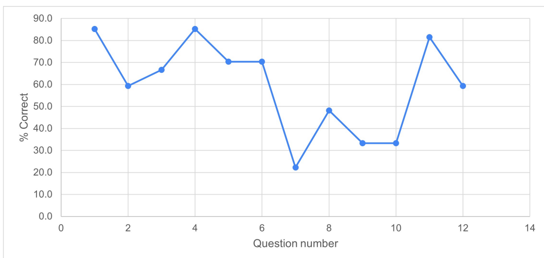

Figure 3: First attempt results on the scaffolding concept inventory

The second concept inventory served as an easily accessible online scaffolding tool for students throughout the module. It specifically targeted the visualization of switching waveforms in power electronics. The concept inventory aimed to provide students with a practice platform to enhance their comprehension and mastery of these concepts. The results of the first attempts for the scaffolding concept inventory are shown in Figure 4.

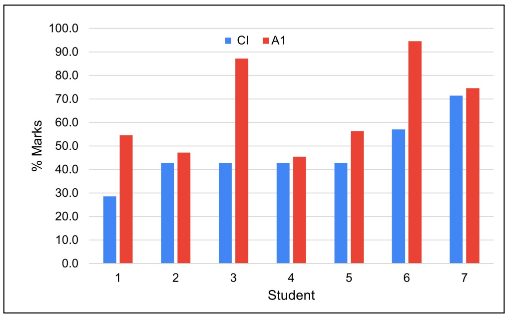

Figure 4

4. Conclusion

From this work, it is clear that a concept inventory can be a useful tool to address student success issues whilst simultaneously promoting social justice in higher education. Concept inventories are valuable tools that can identify misconceptions and gaps in understanding, regardless of students' backgrounds. Instructors can tailor their teaching strategies and resources to bridge these gaps, providing equitable opportunities for all students to enhance their learning. Targeted interventions can be developed to support students, particularly those from disadvantaged backgrounds, fostering inclusivity and equal opportunities for success. Moreover, concept inventories empower students by recognizing their strengths and areas for improvement, fostering self-regulated learning and informed decision-making.

References

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