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Assessing prior knowledge and past experience of commencing Masters students

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ABSTRACT

CONTEXT

Prior knowledge has been widely identified as a key variable affecting student achievement and can be categorised into conceptual and metacognitive knowledge. Students admitted into the Master of Electrical Engineering come from a wide variety of institutions and backgrounds in terms of discipline knowledge, experiences, and exposure to the development of professional skills. Unfortunately, other than an academic transcript, there is no further information available about these elements of their prior study. Any gaps in prior knowledge are therefore unknown, their effects uncertain, and are unable to be addressed in a structured or targeted fashion.

PURPOSE OR GOAL

This study assessed the level of prior knowledge and self-concept of incoming Master of Electrical Engineering students and investigated relationships between these and past experiences. Having a more complete understanding of the cohort via this data means that necessary actions can be performed to either close gaps in content knowledge or build self-concept in identified areas. Furthermore, assessing students' self-concept at the beginning of their degree and periodically throughout it permits benchmarking of the same students to provide a measure as to how it evolves over time.

APPROACH OR METHODOLOGY/METHODS

Students' prior knowledge was assessed through a survey that measured their self-reported level of understanding of electrical engineering topics and exposure to various concepts and skills. Self-concept was measured as a proxy for metacognitive knowledge across several factors. Analysis of relationships between these factors and their possible effects on student outcomes was carried out by analysing academic results in the first semester of study.

ACTUAL OR ANTICIPATED OUTCOMES

This study found strong correlations between self-reported levels of understanding and levels of exposure for each of a set of Electrical Engineering concepts and exposed gaps in some of these concepts. Students had significantly lower self-concept in Communication Skills, however, there was no observable correlation between this and level of exposure to tasks that develop these skills. These results will be helpful to develop supplemental programs to both address some of these gaps in knowledge and to improve self-concept in Communication Skills.

CONCLUSIONS/RECOMMENDATIONS/SUMMARY

This study gave a better understanding of the type and extent of prior knowledge possessed by the diverse body of commencing students and their self-concept in several key areas. Gaps in student prior knowledge and experience and areas of low-reported self-concept have been identified that can now be addressed via appropriate supplemental learning resources, activities or revision of core subject materials.

KEYWORDS

Prior knowledge, student outcomes, skills development

Introduction

The key to developing an integrated and generative knowledge base is to build upon a learner's *prior knowledge* (F.J.R.C. Dochy 1992). Prior knowledge can be defined as knowledge that (F. Dochy, Segers, and Buehl 1999) :

- comprises both declarative and procedural knowledge;
- is present before the implementation of a particular learning task;
- is available or able to be recalled or reconstructed;
- is relevant for the achievement of the objectives of the learning task;
- is organised in structured schemata;
- is to a certain degree transferable or applicable to other learning tasks; and
- is dynamic in nature.

Many studies have identified prior knowledge as a significant variable affecting student achievement (F. Dochy, De Rijdt, and Dyck 2002). A student with inadequate prior knowledge is unlikely to adopt a deep approach to learning, which has also been found to be related to the quality of their learning (Trigwell and Prosser 1991; N. Entwistle and Ramsden 2015). Difficulties caused by individual differences in the prior knowledge base may result in difficulties in completing subjects or degrees; as such, determining the influence of commencing students' prior knowledge is an important aspect for engineering educators.

Learning experiences can be classified based on temporal aspects, encompassing knowledge acquisition, understanding, and the practical application of acquired knowledge (N.J. Entwistle and Entwistle 2003). Another dimension involves the depth of the learning, spanning from memorisation and reproduction to more profound understanding, where learned concepts are applied and connected to prior knowledge. These dimensions collectively create an outcome space illustrating the range of learning experiences and how they may vary. This spectrum encompasses superficial knowledge reproduction transmitted by a lecturer to students, all the way to comprehensive understanding and innovative application of knowledge in new situations. Where students sit on this outcome space is therefore highly dependent on the experiences that they have been exposed to over the course of their studies.

Another factor that influences student performance and achievement is *self-concept*, or their self-perception of ability in a specific domain. Such self-concept focuses on past performance rather than on prospective performance (Marsh and Yeung 1997) and is concerned with how students perceive themselves and their capabilities in particular areas, such as mathematics, on a general level. Students who believe they are not good at something, such as mathematics, may not want to commit themselves and, consequently, experience difficulties in their studies.

Students enrolling in the Master of Electrical Engineering program at The University of Melbourne exhibit a diverse range of undergraduate backgrounds, owing to both the program's inclusive admission criteria and the university's global reputation. Admission to the program mandates a minimum three-year undergraduate engineering or engineering-related degree with a Weighted Average Mark (WAM) of at least 65%. The program is nominally designed for three years, although students might receive credit for up to one year of prior study. All entrants have completed foundational coursework comprising two subjects of first-year mathematics—specifically, Calculus 2 and Linear Algebra—and two subjects of Physics or equivalent.

Despite the minimum WAM requirement, prerequisite subjects, and English language proficiency benchmarks contributing to a baseline competence among incoming students, variations persist. These differences encompass the content of their undergraduate degrees, exposure to practical learning initiatives, familiarity with specific application domains and technologies, and the depth to which certain topic areas were covered. Moreover, undergraduate institutions diverge significantly in terms of extracurricular activities offered and support geared towards enhancing students' professional skills. As a result, the incoming student cohort displays varying levels of prior knowledge, experience and self-concept, which are not necessarily captured through the only information available to course coordinators, in the form of academic transcripts.

It is therefore important to capture the initial state of students, in terms of prior knowledge, experience and self-concept, upon entry into the degree. Having a more complete understanding of the cohort as a whole means that any necessary actions can be performed to either close gaps in technical knowledge, provide additional experiences or address self-concept deficiencies that may hinder their study or are not congruent with the University's broader Graduate Attributes. Furthermore, being able to track students' self-concept over the course of their studies provides a measure of how they are developing towards eventual graduation.

Background

Prior work assessing the self-concept of commencing Masters-level Electrical Engineering students (Buskes 2019) showed that self-concept was weakest in the areas of mathematics and communication skills. While it was proposed that additional testing of students' knowledge in specific topics in mathematics might be required to understand the reason behind the lower self-concept in mathematics, formal testing such as entrance examinations is not possible given the constraints of the institution. For communication skills, it was posited that a contributing factor to low self-concept may be the underexposure of engineering students to opportunities for developing their communication skills.

With this background in mind, a study was proposed to measure student self-concept along similar factors to the prior study, but to also include two additional dimensions explicitly relating to prior knowledge: (1) students' self-reported level of understanding across several topic areas relating to electrical engineering and (2) students' exposure or experience to these topics and other related activities (such as development of professional skills). The objective was not only to gather data on the specific topics covered during their undergraduate degree to look for gaps in knowledge, but to delve deeper into possible reasons for differences in self-concept across the different factors. Unlike the previous anonymous study, students were requested to allow themselves to be identified so that further data such as academic performance could be correlated with the survey data to investigate if any relationships existed.

Method

The survey consisted of three parts: Part A, Part B and Part C. Part A, which was designed to gather more detailed data on students' specific backgrounds in terms of discipline content, consisted of a set of three sub-questions for each of 12 electrical engineering topic-areas, shown in Table 1. For each topic area, the first sub-question asked students to select sub-topics from a pre-populated list that were covered in their undergraduate degree. For example, for the topic area of Applied Mathematics, students could select multiple entries from the following subdomains: Vector calculus, Linear algebra, Probability, Statistics, and Optimisation. There was also an 'Other' option with an associated free text entry box to capture other topic areas a student may have covered not listed. The second sub-question for each topic related to how much exposure they had in that particular area, through asking how often any of the sub-topics they identified in the list were covered over the course of their undergraduate degree. Students rated this exposure level on a five-point scale: Never, Once, Limited, Semi-regularly, Continuously.

Part B consisted of two questions that sought to capture student's exposure to a range of skills development activities over the course of their undergraduate degree. For the first of these questions, students were asked about activities that related to development of professional skills through the curriculum such as working in teams, writing reports and performing guided reflection. Responses were on the same five-point scale: Never, Once, Limited, Semi-regularly, Continuously. The second of these questions related to experiences outside the classroom, such as internships and extra-curricular experiences and used a slightly different scale (Never, Once, Twice, 3-5 times, More than 5 times) as these activities are not continuous throughout the curriculum.

Table 1: Topic areas relating to Electrical Engineering

Physics and Electromagnetics	Digital Electronics	Signal Processing	Programming Languages and Modelling Software
Applied Mathematics	Control Systems	Power Electronics and Power Systems	Operating Systems other than Windows / MacOS
Analog Electronics	Communication Systems	Computer Architecture	Embedded Systems Hardware

Part C comprised of a series of survey items to assess students' self-concept across a range of factors. This survey was based on one previously constructed for incoming Masters students (Buskes 2019), covering the five factors of Mathematics, Academic, Creativity, Electrical Engineering and Communication Skills. There was a total of fifty items for Part C, spread across five factors, with ten items per factor. Each item required students to state how accurately a statement described themselves and provided a seven-point scale ranging from "very inaccurate" to "very accurate" to do so. The fifty items were placed on the survey as statements in a pattern such that every fifth item belongs to the same factor, and items were randomly distributed by direction (positive or negative).

Commencing students were sent an email with a link to the survey inviting them to participate in it. Participants were asked to provide their student ID in order to facilitate cross comparisons with end of semester results and to enable tracking of data for future studies. Furthermore, they were given the opportunity to complete the survey but not make their data available for the study. In all, 24 students completed the survey, with 2 declining to be part of the study.

Results

Results on students' self-reported exposure to a broad range of Electrical Engineering (EE) concepts in their undergraduate degree are presented in Figure 1. High levels of exposure to topics in physics (53.9% above 'Limited'), applied mathematics (61.6%), analog electronics (46.1%) and digital electronics (30.8%) were observed, which are core elements of most undergraduate electrical engineering focused degrees. More specialised areas such as Communication Systems (15.4%) and Control Systems (11.5%) understandably had less exposure, while Computer Architecture (15.4%) and Embedded Systems Hardware (19.2%) had relatively low levels of exposure coupled with more of a bimodal distribution with significantly fewer students choosing 'Limited'. As a likely consequence of the two latter concepts being under exposed, Operating Systems other than Windows and MacOS (7.7%) was the lowest of all.

There were strong correlations between most self-reported levels of understanding and levels of exposure for each Electrical Engineering concept, with Pearson correlation coefficients ranging from 0.602 to 0.855, with most being at the 0.01 significance level, perhaps indicating a strong tendency to automatically associate frequency of encountering concepts with their level of understanding. The only exceptions were Signal Processing, which the level of understanding was not correlated with exposure to Signal Processing concepts, and Operating Systems, which was instead strongly correlated with exposure to Computer Architecture concepts. Figure 2 shows a plot of the average Level of Understanding versus the Average Level of Exposure to EE concepts for each student, showing the significant overall correlation between the two.

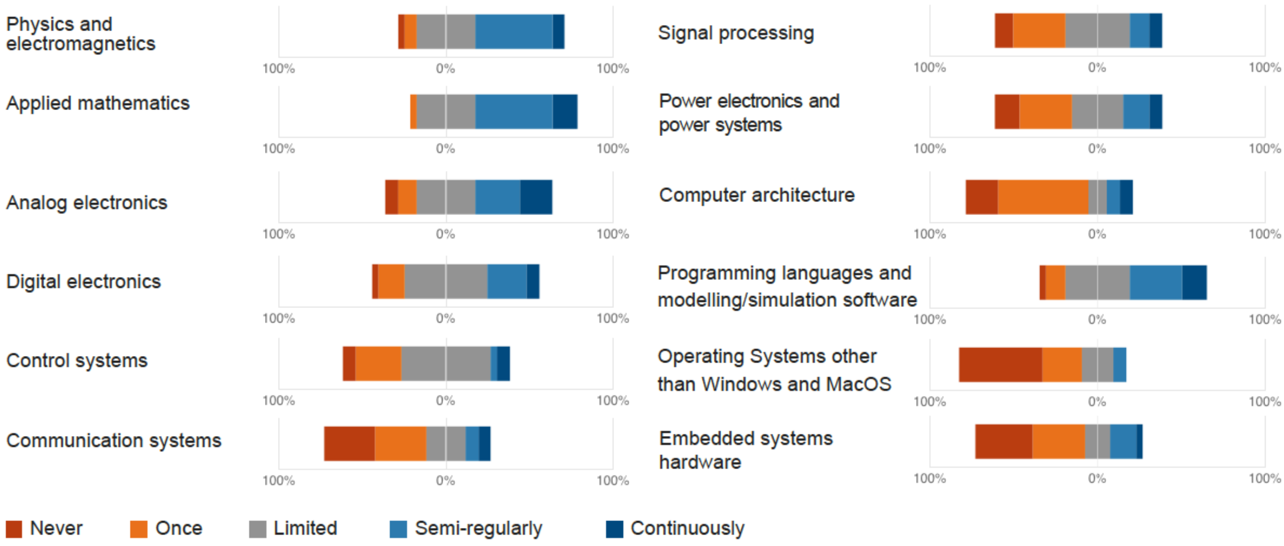

Figure 1: Exposure to Electrical Engineering concepts

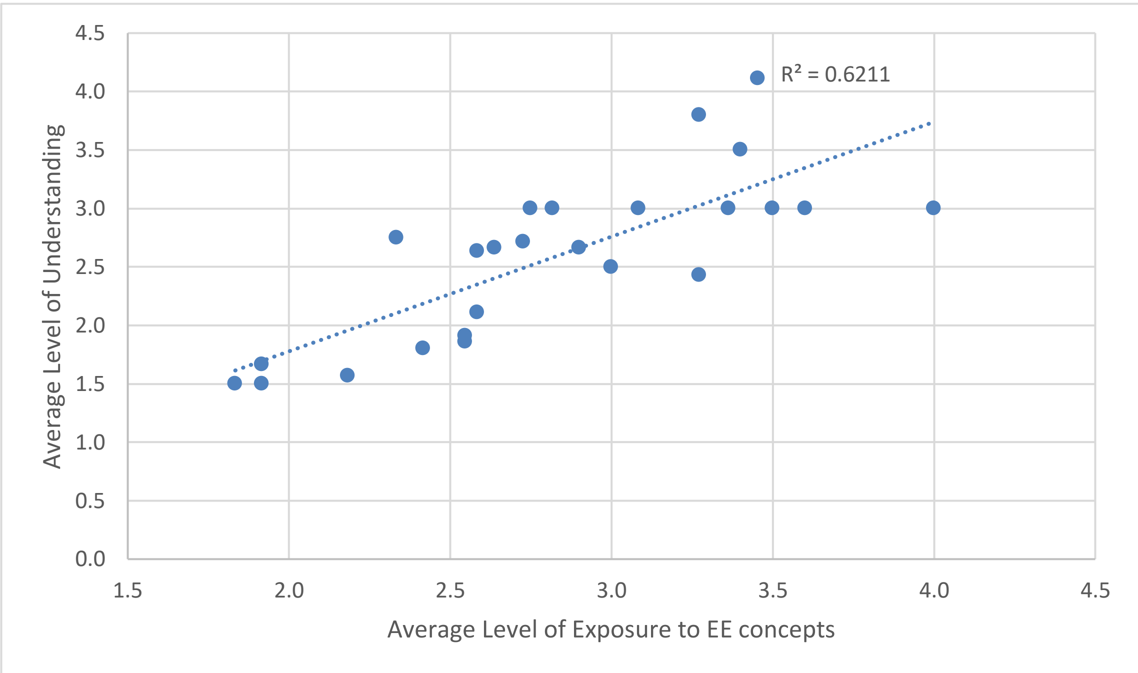

Figure 2: Relationship between Level of Understanding and Level of Exposure to EE concepts

Figure 3 presents results from the survey question, “How much exposure have you had in the following skills over the course of your undergraduate degree?”. It is clear that students had widespread exposure to working in groups on small activities (73.1% reporting more than ‘Limited’), however students had less exposure as the scale of the activities increased to spanning multiple weeks (64%) and then to larger projects (34.6%). The use of team management platforms somewhat mirrors the distribution of exposure to working on larger projects, although the overall frequency is slightly less and there is a more significant proportion that have never used such platforms (30.8%).

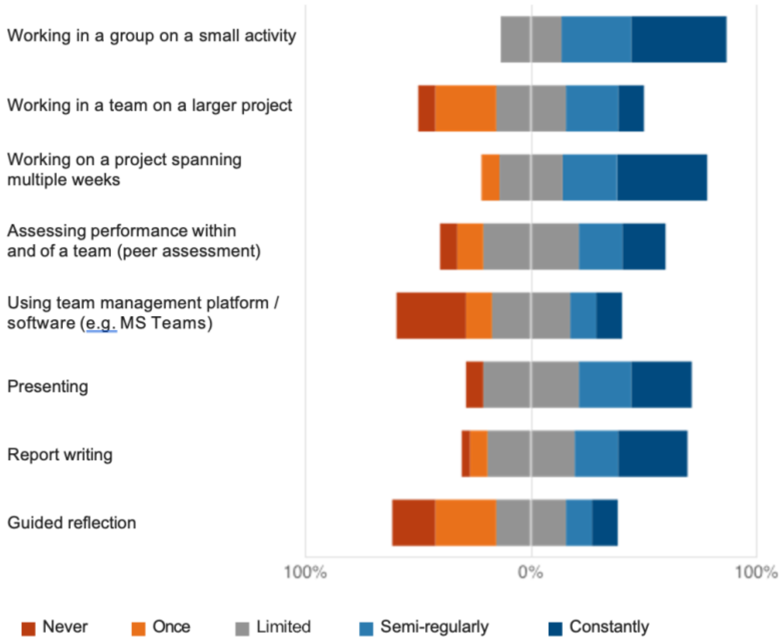

Figure 3: Level of exposure to skills over the course of undergraduate degrees

A large proportion of students have engaged in presenting (50% more than 'Limited') and report writing (50%) during their undergraduate studies, while guided reflection had the lowest amount of exposure, with only 23% of students reporting more than 'Limited'.

When looking at experiences outside the classroom, there was a different story, with all activities having the majority of students select either 'Never' or 'Once' as shown in Figure 4. Most surprising was the response to "Applied knowledge outside the classroom", with 38.5% of students responding 'Never' and 15.4% responding 'Once'.

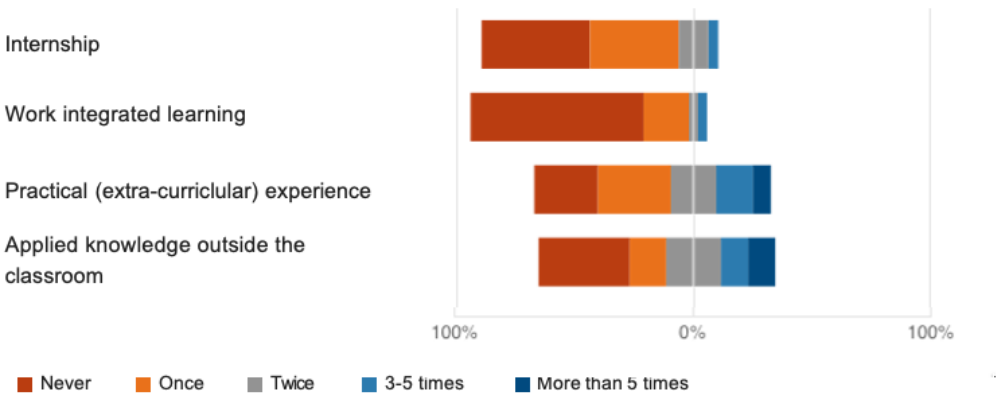

Figure 4: Level of exposure to experiences outside the classroom

Item scores for each self-concept factor were averaged, after reversing items that were negative on the scale, and are shown in Table 2, along with the overall average self-concept across all factors and all students. Strongest self-concept was observed in Electrical Engineering, Academic and Mathematics, which is understandable due to the degree being specialised in Electrical Engineering, at the Masters level and with a minimum WAM entry requirement. This result also correlates well with the relatively high levels of exposure to core topics in Electrical Engineering shown previously in Figure 1.

Table 2: Self-concept factor averages

Self-concept factor	Average score
Mathematics	73.8%
Academic	75.0%
Creativity	70.4%
Electrical Engineering	76.2%
Communication Skills	66.1%
OVERALL	72.3%

Communication Skills had the (statistically significant) lowest self-concept, which echoes a previous study of incoming Masters students (Buskes 2019); however, there was no observable correlation between self-concept in Communication Skills and level of exposure to either Report Writing or Presenting. This could indicate that while students are broadly being exposed to such skills, they are not receiving adequate feedback on the level of their skills in order to continue developing them. The lack of exposure to guided reflection reported by many students in Figure 3 could also be a factor in lower reported self-concept for Communication Skills.

Student results in their first semester in the Masters degree were analysed in order to determine if differences in academic performance could be described by the data and factors collected in the survey. Students' WAMs were used as a proxy for academic performance due to the relatively small amount of students in the survey and the fact that they can take different subject combinations in their first semester. Notably, there was no statistically significant relationship between overall self-concept and WAM, overall exposure to concepts and WAM, or self-reported level of understanding and WAM. It is, however, worth noting that the two students who dropped out of their degree mid-way through semester were in the bottom three in terms of average self-reported level of understanding.

Discussion

Analysis of survey data provided insightful findings regarding the starting cohort; notably, students exhibited strong self-concept in technically-related content but weaker self-concept in Communication Skills. Interestingly, this weaker self-concept persisted despite students having opportunities to practice skills like presentations and report writing. Despite displaying a robust self-concept in Electrical Engineering, students reported limited exposure and understanding of specific Electrical Engineering concepts like Embedded Systems Hardware, Computer Architecture, and Operating Systems. This concern aligned with feedback from subject coordinators teaching related subjects. Addressing this discrepancy is vital, particularly since Embedded Systems is a core subject in the Masters program.

Unfortunately, use of WAM as a predictor for academic performance might be too coarse in order to make meaningful observations about relationships between the survey data collected as students commenced the degree and their end of semester academic performance. This could be mitigated by utilising individual subject results and matching these to survey results from particular relevant items. In order to achieve this, more subject results data would need to be gathered over subsequent semesters to ensure certain subject areas, for example, Communication Systems, have enough results to process. Students have some choice in the subjects they take in their first semester which results in low numbers of survey participants in some subjects and the need to gather more data over time. However, even after observing results at the subject level, the aggregation and varied weighting of multiple assessment items might obfuscate some of the relationships between topics on the survey and academic performance in those topics. It would be instructive in the future to investigate individual assessments in subjects that might align with some of the factors surveyed at the start of semester. For example, if a subject has a presentation in it as part of the assessment, this result could be correlated with the survey item relating to exposure to presenting.

The level of understanding sub-questions were self-reported by students, which might not necessarily correspond well to their actual level of understanding and tended to align with level of exposure. Furthermore, when calculating average scores for students' level of understanding and exposure to concepts, equal weighting was applied to all survey items. This approach may not accurately reflect the relative importance of different topics and future investigations could explore the feasibility of assigning relative weightings to items. Completing topic-specific concept inventories or entrance exams might provide a more reliable measure for this in the future, although the length of the survey would be considerably lengthened.

Conclusion

This paper presented the results of assessing prior knowledge and experience in Electrical Engineering topics and self-concept across a range of factors of incoming Master of Electrical Engineering students through an online survey instrument. The survey data highlighted some areas for improvement in terms of exposure to opportunities for skills development and the need for targeted subject-level interventions in certain topic areas. While it was not possible to directly relate academic performance, as measured by WAM, to the survey data, it has emphasised the need to perform a more thorough investigation at the subject level and possibly consider performance on individual assessment items. Through capturing student identification as part of this survey, it is envisaged that the same students can be assessed again throughout their course to benchmark their exposure to Electrical Engineering topics and professional skills building activities and further understand how their self-concept evolves over time.

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