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Material selection in Electric Vehicle Engineering Programs

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Abstract

No one could have missed the transition towards electrification in society, with the surge in electric cars and other vehicles on the streets around us. This is partly driven by the realization that fossil fuels need to be phased out and partly by other environmental concerns. It is also boosted by technological developments of battery performance, enabling more energy to be stored electrochemically using new and better materials. Furthermore, there are new appealing modes of transport, such as electric skateboards, hoverboards and monowheels. Such topics are popular with students of mechanical and electrical engineering, as well as in product development and design projects.

In this paper, we describe how sustainability and design have been systematically introduced, using a materials approach, into an undergraduate program of electrical engineering (EE) with electric vehicle specialization as well as in a one-year graduate program on electrical vehicle engineering. This was done using three materials-focused computer labs, dealing progressively with (i) material properties and selection, (ii) eco design and lifecycle thinking and (iii) battery design, each embedded within a different EE class. A well-known materials education software, Granta EduPack, covering all these areas was used as the learning platform.

The purpose of the study was to gauge the interest and perceived usefulness of materials knowledge by around 40 EE students using this approach. It was conducted by integrating 5 survey questions into the end of student assignments before and after the second lab instalment mentioned above (eco design and lifecycle thinking). Both groups think MS&E is quite interesting (3.6-4.0 out of 5). They also think materials and material knowledge are important to their education (4.1-4.4 out of 5). As additional information that could be extracted from the surveys, we learned that the computer lab itself resulted in a significant increase in the self-assessed knowledge and skills linked to the content. We conclude that elements from materials science and engineering can be a successful and well-appreciated approach to introducing sustainability and design into non-mechanical engineering programs, such as electrical vehicle engineering. With this paper, we are hoping to share details and experiences of this materials-led approach and get feed-back from the wider materials community.

Introduction

Most forms of engineering make use of materials in some way. After all, everything around us is made of materials. Even digital and virtual based professions and applications rely on specialized high-performing materials to transfer and store data [1]. Energy related industries and electrical engineers are also reliant on advanced materials for generation (magnets) and storage (electrodes). The world Bank Report 2020 highlighted 17 mineral resources that are essential to a clean energy transition towards renewables [2]. We know that material production and related activities contribute more than 20% to the global greenhouse gas emissions [3].

In this paper, we want to explore a materials-based approach centred around sustainability and design that was introduced into electrical engineering (EE) programs with electric vehicle specialization both at undergraduate and graduate level. This has been done using materials-focused computer labs. A well-known materials education software, Granta EduPack [4] (hereafter referred to as the software), covering these areas in mechanical engineering and design curricula was used as the teaching platform. The main two research questions that were investigated was firstly: is materials science and engineering content interesting to electrical engineering students in the field of electric vehicles and secondly: is material knowledge perceived as relevant to their education. Furthermore, we wanted to know if the software and the lab approach itself were useful.

Background

Materials Science and Engineering is a subject taught as a 7.5 credit course module for undergraduate Mechanical Engineering (ME) students at University West in Sweden, which has close links with the automotive and aerospace industry in the region. In order to support materials selection, eco design and sustainability in the ME program, practical computer labs using an established software [4] is in use. When designing the curriculum of two relatively new educational programs, one undergraduate Electrical Engineering (EE) with electric vehicle specialization and another one-year graduate program, entirely focused on Electrical Vehicle Engineering, it was suggested to incorporate materials-related components in some course modules to cover environmental issues and sustainability in a constructive way. There is no requirement of prior knowledge in materials-related subjects to be admitted to these programs, delivered by the Department of Engineering Science.

Three separate EE course modules within these two programs that were pairwise similar in content were targeted, each suitable for lectures and computer labs (2+2h) using the software. Experiences from the ME program were drawn upon, dealing progressively with (i) material properties and selection, (ii) eco design and lifecycle thinking and (iii) battery design. This paper report findings concerning self-assessed student attitudes from before *and* after computer lab session (ii) on eco-design and lifecycle thinking. This lab was scheduled at the beginning of the course module *Electric Machines for Electric Vehicles* and the respondents already had some introductory experience of the software and materials data from lab session (i) about 10 weeks earlier. Around one week after this session, they were expected to have acquired knowledge on eco design and lifecycle thinking, following the lecture and computer lab, as they were required to hand in assignments linked to this content.

Methodology

The study was conducted by integrating 5 survey questions into the end of student lab preparations and assignments, clarifying that these survey questions were being made voluntary and anonymous. This ensured that the response frequency was very high. Two groups were consulted, one undergraduate, n=15 (relatively homogenous in age and ethnicity) with campus students taught in Swedish, and one graduate, n=24, from a more diverse (nationality) one-year Master program mixed online (58%) and Campus (42%) students and taught in English. The survey questions were given both at the start of the course module, with required preparation before the computer lab, as well as with the lab assignment to hand in after the lab. The questions are shown in Table 1, below.

Table 1. The survey questions rated by students, ranging from 1 (not much) to 5 (very much).

A How interesting do you find materials science and engineering?
B How would you rate your knowledge about engineering materials and advanced materials?
C How relevant do you think materials and material knowledge is for your education
D How skilled do you estimate yourself to be using the EduPack software
E How useful do you think this software is for you

The alternatives for answering were numerical, from 1 (very little) to 5 (very much). A few non-integer answers were submitted and accepted. Questions D-E were mainly used internally for course quality control but average values from all five questions are reported.

Results and discussion

The average score from the surveys before (*pre*) and after (*post*) computer lab (ii) for both groups of students are given in Table 2. The answer frequency was very high, since the survey was conducted in connection with mandatory lab preparation and the lab assignment, respectively (the survey, however, was not mandatory, as explained to the students). 14 out of the 15 undergraduate students completed the surveys (*pre* and *post*). 22 out of the 24 graduate students that completed the *pre* survey, also completed the *post* one.

Table 2. The survey results, showing the average rating by students.

Question	**Undergrad**		**Graduate**	
	pre	*post*	*pre*	*post*
A How interesting do you find materials science and engineering?	**3.79**	**3.57**	**3.96**	**3.91**
B How would you rate your knowledge about engineering materials and advanced materials?	**2.43**	**2.75**	**2.42**	**2.95**
C How relevant do you think materials and material knowledge is for your education	**4.43**	**4.07**	**4.32**	**4.18**
D How skilled do you estimate yourself to be using the EduPack software	**2.2**	**3.07**	**2.54**	**3.14**
E How useful do you think this software is for you	**3.04**	**4.14**	**4.14**	**4.125**

Both groups think *Materials Science and Engineering* is quite interesting, 3.6-3.8 for the undergraduates and slightly higher, 3.9-4.0 for the graduate students. This is after previous introduction to the topic in computer lab (i) less than three months earlier in a previous course module, so it is considered an informed self-assessment. This (Question A) answers the first research question of the paper. The second research question addresses the perceived relevance of materials knowledge for their education (Question C). This was rated even higher by both student groups, 4.1-4.4 for the undergraduates and 4.2-4.3 for the graduate students.

The relatively high level of interest might be explained by the strong perception of relevance, but it is interesting to note that both aspects dropped slightly in both groups following the computer lab itself. Possibly influenced by the assignment effort preceeding the post survey but perhaps also reflecting a disappointment regarding the acquired knowledge or even a more accurate perception of the subject. This is one takeaway point from the study.

Since this study was a first, conducted on these engineering programs, there is no reference level to relate these results to. A similar survey, however, was conducted at the first lecture of a Materials Science and Engineering course module for second year undergraduate ME students at the same department. This survey contained the same question: "How interesting are materials and materials science to you?" rated on a three-level multiple choice scale (a little, medium/don't know, a lot). The average result from 33 respondents was very close to 2 out of 3 (or 66%) if translated into numerical values, compared to a total average of 3.89 out of 5 (or 78%) for all the EE students *pre* lab (ii). This lower result for ME students may be an effect of the limited choice in answers, forcing respondents to chose 2 rather than 3, even if the actual rating would be above medium if given the option. It indicates, nevertheless, that materials and materials science probably does not rate less interesting for electrical engineering students than for mechanical.

The question of relevance in the present study can be compared to the similar question to ME students: "How important do you consider knowledge about materials to be?". This resulted in a high rating of 2.53 out of 3 (or 84%) for ME students, using the same numerical translation. This is even higher in the average rating from the total cohort of EE students, 4.34 out of 5 (or 87%) *pre* lab (ii), indicating that the subject of materials and materials science is perceived as relevant to broader groups of engineering students, at least for electrical vehicle engineering.

As additional information that could be extracted from the surveys, we learned that the computer lab itself resulted in a significant increase in the self-assessed knowledge and skills linked to the content. The increased knowledge (10-20%) and software skill (20-40%) indicate a very positive outcome, which is further supported by an average rating of over 4.1 regarding the usefulness of the software following the lab.

Conclusion

Both study groups think materials and material knowledge are interesting and important to their education and the results indicate that the lab and the approach constitute a successful course module. One surprising finding was that both interest and relevance decreased slightly after the lab, although from high levels. This is taken to mean that there is room for improvement in managing expectations and, hopefully, that the relevance and interest levels can be restored and enhanced during the final course module (iii), still to be assessed. We also conclude that elements from Materials Science and Engineering can be a successful and well-appreciated approach to introduce sustainability and design into adjacent engineering programs, such as electrical vehicle engineering.

References

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