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Use of engineering cases as alternative assessments in material characterization course

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Abstract
Materials Characterization is a Year-4 level undergraduate course introducing both fundamental principles and applications of various characterization techniques. In order to effectively achieve the learning objectives and enhance the competitiveness of undergraduate students in their career choices and in further advanced study, we have introduced engineering cases as alternative assessment methods. This paper has discussed how the engineering cases are designed and constructed for students to apply the acquired knowledge and techniques to tackle practical problems, as well as the benefits of adoption of this pedagogical approach. Components of engineering case are described and the mapping between the components and course contents is also elaborated. Effectiveness of engineering cases is reported.

Keywords: *engineering cases; assessment; effectiveness.*

1. Introduction

Project learning and experiential learning have been widely applied across a diverse range of subjects. When it comes to specific subjects, there are mainly two challenges to overcome. Firstly, there are always areas that needs further customization and refinement for a specific subject. For example, Aziz et al (2008) introduces product engineering cases to freshmen to understand the general mechanical systems. Sheng et al (2014) has shared experiences of using engineering application cases in teaching hydraulic and pneumatic course to improve students' problem solving skills and inspire their passion and enthusiasm in this course. Herget (2020) has explored integrating project-based learning into foreign language learning. In order to guarantee effective learning outcomes, various innovative learning methods such as case studies have also been applied across a wide range of areas. For example, Freeman et al (2020) has developed a live case to carry out analysis of a national tourist attraction. Secondly, the fair and efficient evaluation methods are needed to assess students' work. Tran et al (2020) have adopted test-driven methodology and provided a clear benchmark for project implementation to allow students to self-evaluate their work progress. Bryceson (2020) has compared existing marking scheme for assessing group project with a new marking scheme incorporating peer evaluations. Richards (2017) uses real products as cases to inspire students for critical thinking, decisión making as well as exercising communication skills in a design thinking course.

Materials Technology is one of the key research and teaching areas of our Mechanical and Aerospace Engineering (MAE) department. Materials option is one important in-depth option for undergraduate students in MAE department. Materials selection and application are common core engineering practice and are determined by the mechanical properties and performance, which are in turn strongly dependent on chemical composition, microstructure, and morphology of materials.

Modern mechanical engineering is a highly interdisciplinary field and covers sub – fields such as solid mechanics and dynamics; energy and thermal fluid; design, manufacturing and automation; microsystem and precision engineering; as well as aerospace engineering. Each of these sub – fields involves various innovative materials and calls for different materials characterization techniques. Our students, either during their internships, or during project works in their career, or during research in their advanced study program, are faced with selecting, utilizing, and analysing different materials. For example, the situation may be failure analysis of boiler wall materials in power plants; or microstructural observation of soldering materials in a PCB board; or thermal analysis of certain heat dissipation materials; or phase composition of some novel alloys, and so on. Therefore, knowledge and hands-on experiences of materials characterization are indispensable and serve as a key tool for our students to tackle various materials problems. Materials Characterization is a Year -4 level undergraduate course intended for the above mentioned objectives with various materials characterization techniques. This course explains both the fundamental principles and the applications of each technique, such as observation of microstructures with light microscopy, SEM, TEM, SPM; application of X-ray techniques to identify crystal structures (XRD) and to identify elements (XRF); surface analysis with XPS, AES, and SIMS; molecular analysis with vibrational spectroscopy; as well as thermal analysis.

In order to enhance the competitiveness of undergraduate students in their career choices and in further advanced study programs, we have designed and constructed four engineering cases for them to crack during the course learning process. The four engineering cases have been used as one of the assessment tools in material characterization course. Each engineering case simulates the real industrial (project work) environment, and is designed in such a way that students have to crack the case using their learned knowledge throughout the course, and finally implement it. In other words, students will keep in mind of the practical aspects of each engineering case and potential applications of each materials characterization topic they are learning in this course.

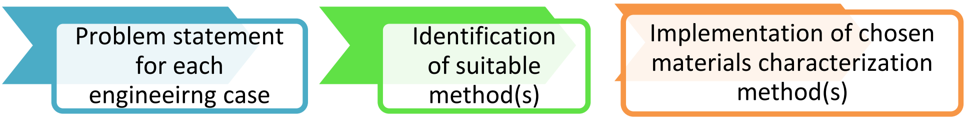

Figure 1. Steps of the process

2. Engineering Cases

The idea of using cases to assist teaching and learning is not new. In fact case studies are widely employed especially in educations in business and law field. Among various learning objectives, application of the acquired knowledge is very important for students to develop their professional skills and prepare for their careers or further studies. The challenges lie in two aspects, i.e. one is to effectively integrate different knowledge modules in this course into various cases; the other is to fairly and effectively grade students' work. In this session, we will describe how we have designed the cases and how we have measured students' learning outcomes.

2.1. Design and construction of engineering cases

Each of the four engineering cases consists of three components for students to work on: i.e. i) "Theoretical Concepts" which are in the format of multiple choice questions and are intended to test students' understanding on the fundamental principles and theories of characterization techniques; ii) "Crack the Case" is a simulated industrial case where an industrial scenario (or a product application or an engineering problem) is described and further analysis requires students identify suitable characterization techniques and elaborate on procedures as well as interprete provided data; and iii) Extended Reading is a research publication specifically using a certain characterization technique for a specific application. In-depth questions are asked about the testing data. Students are encouraged to help interpret the data and explain reasons for some uqniue results in certain data.

Table 1. Components for engineering cases

Components of each case	Assessment criteria
Theoretical concepts	Able to explain the principles of characterization methods;
Crack the cases	Able to identify suitable characterization methods;
	Able to interpret the experimental data and explain the related phenomena
Extended reading	Able to explain the phenomena with related experimental data and interpret the data;
	Able to justify or question whether current characterization methods are suitable and whether other methods may be better

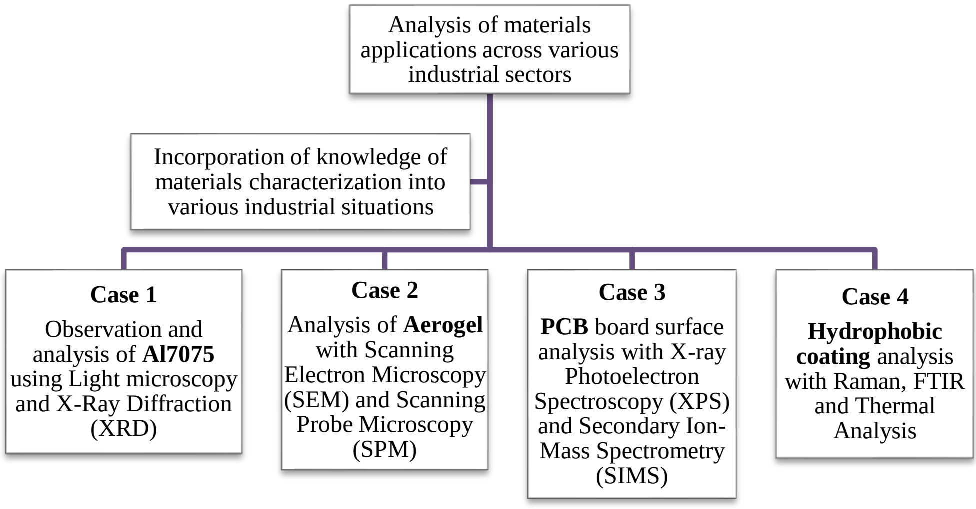

Figure 2. Mappting of each engineering case and the course contents

2.2. Results and discussion

In order to test the effectiveness of using the four engineering cases in this course in helping students achived their learning objectives, we have performed a survey after students completing each engineering case. The survey questions and scoring scheme are listed in the following Table 2.

Table 2. Survey questions for each engineering case

Survey questions for all four cases	Score range
Assessment (i.e. regarding difficulty level, the workload required, and whether the questions with fixed and predetermined answers fit the course learning objectives)	Min. 1 (Strongly disagree); Max 5 (Strongly agree)
Knowledge comprehension / application (i.e. how the three components of each case helped the students better understand and apply what was taught through lectures)	Min. 1 (Strongly disagree); Max 5 (Strongly agree)
Alignment (i.e. how each case is aligned with learning objectives)	Min. 1 (Strongly disagree); Max 5 (Strongly agree)
Surface learning (i.e. level of memorization needed)	Min. 1 (Strongly disagree); Max 5 (Strongly agree)
Deep learning (i.e. high – level learning)	Min. 1 (Strongly disagree); Max 5 (Strongly agree)

Source: Internal Survey Data

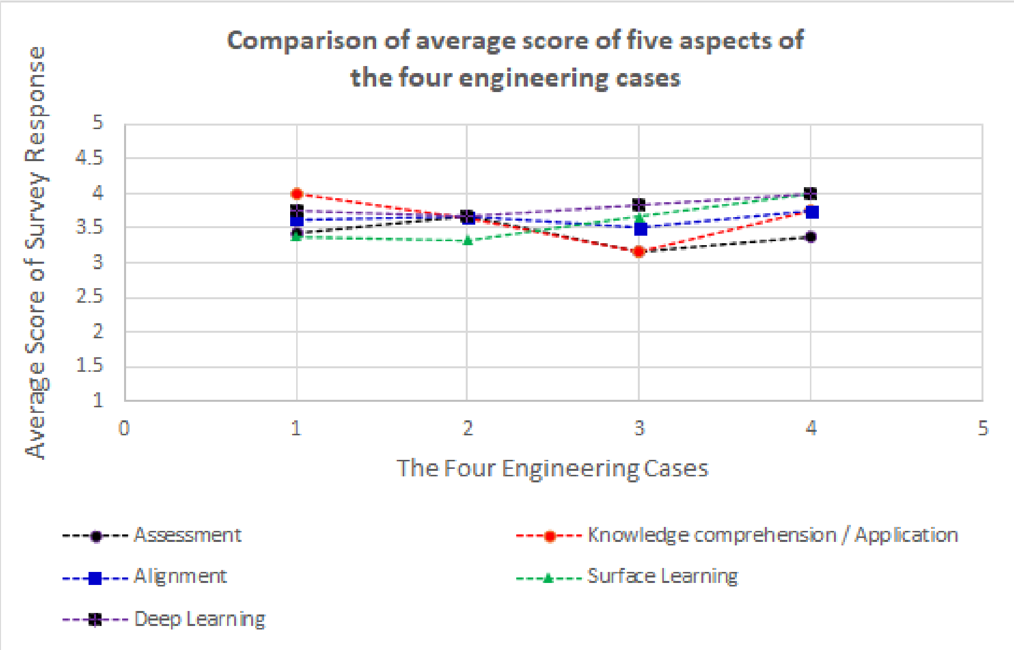

Figure 3. Comparison of average score of the survey data for the four engineering cases

The average score of survey data for each engineering case is plotted in Figure 2 above. It is found that all average scores are within the range of 3 to 4. Regarding the results on "Assessment" and "Knowledge Comprehension / Application", case 3 receives the lowest score probably due to the case complexity and difficulty level increase. This also indicates that case 3 will need re-design in the future. All four cases have received consistent scores for "Deep Learning", which means all four cases help students have in-depth and critical thinking about the application of characterization methods. The consistent scores in :Alignment" also indicates that each case is aligned well with the planned learning objectives.

2.3. Benefits of using engineering cases in this course

When conducted surveys which are not only with numerical scores, but also open-ended comments. The overall comments are positive in terms of the usefulness of the engineering cases in helping students further understand fundamental concepts. Some comments give us constructive suggestions for future course teaching. Below are some comments highlighting the benefits that students have experienced by cracking these cases.

Table 3. Open-ended comments from students

When students were asked if it is necessary for the course to include regular cases to work, the majority noted the usefulness of the cases for their learning:
Yes. It's another form of assignments which help students to consolidate what they learned from lectures.
Yes, I think it is important as it provides a certain application to our learning and makes the study more 'useful' in the sense that I can understand how to actually apply my learning to a real-life problem.
Yes, it can lead us to learn the application and implication of technology.
Yes, as the case studies expose students to more realistic cases after graduation.
It is important to have it as it is not something we can directly copy from the textbook and lecture notes.

Source: Internal Survey Data

3. Conclusions

Four engineering cases are successfully designed and constructed and are mapped with course contents. Assessment criteria are applied to evaluate students' performance in the cases. According to our internal survey results, all four cases have received positive feedbacks from students in all five sets of survey questions. All cases have reflected and well matched with the course contents. Although most students feel that engineering cases are more difficult than traditional assessment due to the fact that more critical and in-depth thinking is required to crack each case, when an open-ended questions asks if it is necessary to include regular cases, majority of students think it is useful to do so. For example, some said "*Yes, I think it is important as it provides a certain application to our learning and makes the study more 'useful' in the sense that I can understand how to actually apply my learning to a real-life problem.*"; "*Yes, it can lead us to learn the application and implication of technology.*"; "*Yes, as the case studies expose students to more realistic cases after graduation.*"; "*It is important to have it as it is not something we can directly copy from the textbook and lecture notes*". As case 3 receives lowest score in the items of "Assessment" and "Knowledge Comprehension / Application", in the future, case 3 will be re-designed and improved in this two aspects.

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