A problem formulation project in Statics for connecting the theory to daily application

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Abstract

A project was an integrated part of the Statics course as the means towards the desired ability: the problem formulation, approximation and hand-on experiences. Students started to recognize mechanical structures in everyday life. Then, they had to study, formulate a well-defined problem by approximation with numerical justification before analyzing the structures. A table of rubric was used in the marking process to ensure a standard across the class. A side effect of the rubric was less complicate structures were selected for study as students strived to minimally satisfy the marking guideline. This situation was acceptable as the simplistic structures required all main learning components. The project also tried to account for some program outcomes that were obtained by thorough integration into the curriculum, namely the basic experimental skills on measurement and the academic honesty. Even though these program outcomes were not fully realized, they were but the first step which was to be repeated and reinforced.

Keywords: Statics, problem formulation, marking standard, outcome, plagiarism

1. Introduction

At Chulalongkorn University, Thailand, the 2103211 Statics was a basic compulsory course for bachelor programs offered by the Departments of Mechanical Engineering and Industrial Engineering in the 2002 curriculum revision. About 200 second-year students from both departments registered for the course annually. For the newly 2011 revised programs, the industrial engineering program dropped the course in favor of the more compact 2013213 Mechanics I which combined contents from Statics and Dynamics. Thus, the number of students in the 2012 academic year would be halved and that represented a new opportunity for the course management.

Even though a major focus in Statics was the solid foundation of concepts and procedures, a problem that had to be addressed was the students' lack of engineering senses. As students entering engineering programs in Thailand were selected according to their academic performances and vocational students were not eligible to enter, there was a severe lack of hand-on experiences as well as role models. Moreover, the program outcomes demanded the ability to formulate problems as the first requirement for design.

As students selected the engineering disciplines at the end of the first year, Statics was among the first in the programs that encountered this problem. Hence, the last of seven course objectives specified that students must be able to model problems in Statics by (a) describing the physical meanings of idealized problems in Statics and (b) approximating real-life problems to idealized problems with appropriate justification.

For this objective, a small project was considered a direct means of ensuring the learning. Several types of project were employed since the objective was introduced. In 2002 and 2003, groups of students were told to design, built and test a truss bridge under a restricted budget. The 2004 project involved the combination of analyses, experiments as well design, built and test of small models. The project was then changed to the truss bridge optimization, followed by designing and testing heavy duty paper bridges in 2006.

While these projects were quite popular with students, the running required lots of efforts from lecturers, including the need to supervise the material testing, workshop and spaces, etc., for so many students. The workloads were sufficiently overwhelmed that it was decided to move on to a less demanding project type. However, the real-

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life, hand-one experiences had to be retained. Lecturers concluded that a project that involved the problem formulation might be the best answer in terms of direct assessment and efforts. In addition, students had the chances to select structure of interests and be more aware of applications in everyday life.

2. Project Descriptions and Management

The project instruction was sparse: "The project involves the formulation and analyses of a real machine at a specific situation by measuring dimensions, drawing sketches, and/or taking photographs, i.e. gathering the information necessary to analyse the device. By making reasonable assumptions with numerical justification, an idealized problem can be formulated. Then determine all forces/loads exert on members of the structures under a realistic condition. You will form a group of 2 and submit a short technical report of no more than 4 pages long, excluding appendices. The cover page and scoring rubric is given in the next page. Recommended sections are (1) structure descriptions, (2) approximation/idealization and (3) analyzed results. Detailed analyses must be consigned to the appendices."

In 2007, project reports were equally divided for marking using a qualitative approach; in 2008, they were grouped by topics for better standard of marking across the structural type. For better uniformity, a simple marking rubric was introduced in 2009 and the guideline had been continuously refined and modified since then. These marking guidelines were given to students alongside an example report with stated emphasis on the desired performances and outcomes. The concept was to reduce the burden on documentation and focus on the technical sides.

Students could consulted lecturers on structural selections and asked for clarification on problem approximation and idealization. It could be observed during the process that students started to recognize the structures that were integrated parts of everyday life. With the introduction of rubric guidelines in 2009, students became more discriminate about the selection as many just wished to satisfy the guideline without unnecessary difficulty. This resulted in the downfall of complicate structures, particularly exercise machines and garage tools that were so popular in the first years in favour of less complicated, small appliances or folding furniture. In additions, these simple structures that could be readily acquired, or broken down in needed, were far more easier to measure dimensions, made up or measure realistic loads and provide the numerical justification. Hence, it was clear that the project was influenced and could be effectively manipulated by adjusting the marking guideline.

Table 1. The number of structural selection by year

Structure Type	2009 Class	2010 Class	2011 Class
Large machinery (e.g. boom, lifts, crane, mounted platform, basketball stand)	14	1	0
Exercise machines	29	20	9
Garage/garden tools (e.g. pliers, car jack, foot pump, clamp, pruner)	23	16	10
Foldable furniture (e.g. table, chair, ladder, clothes hanger, instrument stand)	12	26	42
Household appliances (e.g. lamp, cleaning tool, bin, cart, umbrella, toilet flusher)	12	18	16
Small utensils and stationary (e.g. hole puncher, stapler, nail clipper, eyelash curler)	6	16	19
Total	96	97	96

3. Assessment by Rubric

The project is evaluated in areas of (1) problem selection & description, (2) problem idealization, (3) structural analyses and (4) documentation. The detailed rubric of each area is given in Table 2. For each criteria, 4 rating levels – yes, mostly, no or negligible and not applicable – are used to measure the performances. These levels are converted to 100%, 65%, 0% and 100%, respectively. The evaluation criteria are all available to students as a part of the covering page of the project report. Students were also asked to self-assess their own project before submission.

Table 2. Scoring rubric for the project

Item	Evaluation				
	Weight	Yes	Some	No	N/A
1. Problem selection & description (20% of total)					
1.1 Selection of a real structure that can be measured.	40%				
1.2 The structure is of sufficient complexity.	30%				
1.3 The structure is well-described, e.g. with photo, model and materials.	30%				
2. Problem idealization (40% of total)					
2.1 Appropriate use of measuring instruments and accuracy	20%				
2.2 Complete dimension measurements for analyses *	20%				
2.3 Appropriate approximation of applied loads *	20%				
2.4 Appropriate specification of supports	20%				
2.5 Other approximations, e.g. 2-force members, are made appropriately. *	20%				
3. Disassembling and Analyses (30% of total)					
3.1 Correct identification of components/members for disassembling	15%				
3.2 Draw FBDs in correct forms and appropriate arrangements	15%				
3.3 Correct identification of support reactions	15%				
3.4 Correct identification of reactions between components/members	15%				
3.5 Correct calculation of unknowns with acceptable procedures	15%				
3.6 The solutions are assembled in the main FBDs.	5%				
3.7 Appropriate axes definition and unknown labelling	5%				
3.8 Appropriate uses of significant figures	10%				
3.9 Appropriate uses of suffices for units, particularly for solutions	5%				
4. Report and Documentation (10% of total)					
4.1 Clear, concise and neat report	40%				
4.2 Appropriate uses of tables, diagrams or other visual effects	30%				
4.3 Appropriate uses of appendices	30%				

* Reasonable approximation and justification with supporting numbers.

Even though the rubric could guide students towards the desired goal and helped with the marking, it was not without criticism. Lecturers were asked to mark all reports according to the overall quality. The marks were plotted against the rubric scores in Figure 1. These quality-based scores expectedly exhibited a high variation between different lecturers. Even when the overall distributions were similar as those of Lecturers A and B, the direct comparison on the rightmost graph showed high individual differences. When further explored, it was found that the differences were mainly due to 3 factors. The first concerned with the difficulty of the structures in which complex structures offered more opportunity to impress. The second was the writing and presentation skills in which the rubric marking placed less emphasis. The third was the lenient level assignment in rubric in which marginal cases were favored.

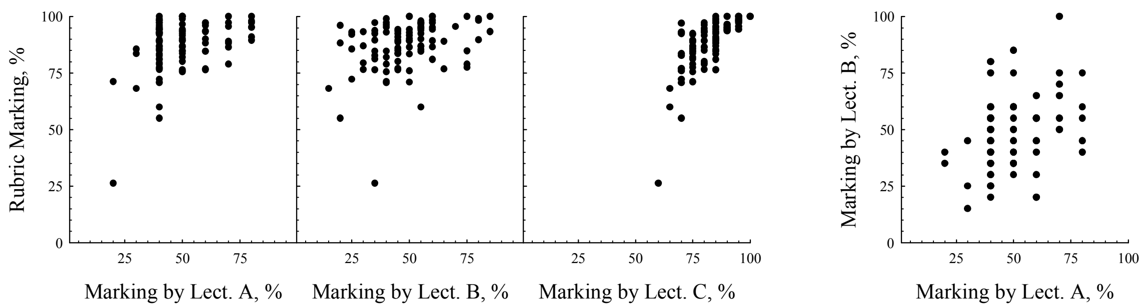

Figure 1. Comparison between the rubric and quality marking by 3 lecturers

4. Complementary Outcomes

With the on-going reform in higher education in Thailand, the trend has, for the last few years, gravitated towards outcome-based outlook. Continuously evolved regulations, both in educational policy and professional practices, respectively embodied by the Ministry of Education and the Council of Engineers, has posed a real challenge to the management and development of engineering programs (Pimpin, Maneeratana, 2010). The 2002 revised mechanical engineering program at Chulalongkorn University adopted the outcome-based approach while had to satisfy the strong content-based requirement of the Council of Engineers.

The program administration tried to satisfy both requirements and ensure the quality by integrating the contents and outcomes together (Figure 2). The contents were represented by vertical blocks which, for the courses under the Department, could be divided into groups – solid mechanics, thermo-fluids and dynamic & control – according to the academic/research divisions within the Department. Curriculum outcomes were assembled into 3 main groups – design, experiment and other skills. Dedicated working groups were responsible for integrating outcome-oriented activities into courses across the curriculum as denoted by the horizontal arrows. The program outcomes were assessed and the feedbacks were concentrated to courses within the Department due to the much higher level of communication, priority, and promptness in the uses of feedbacks and responses.

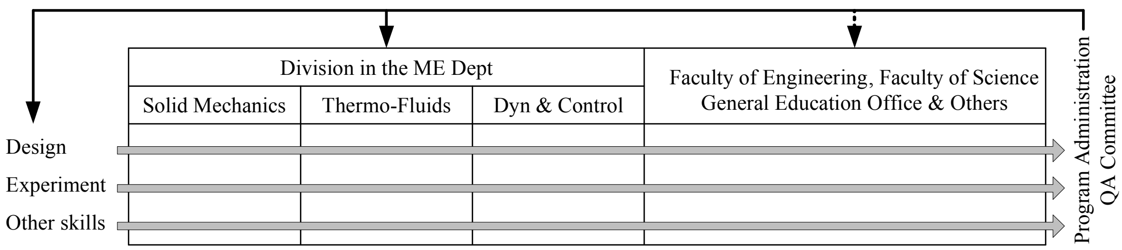

Figure 2. Program management overview

The three horizontal streams were derived, grouped and prioritized from the list of desired engineering graduate attributes. It was noted that the third horizontal ‘other skills’ stream, comprising of soft skills and tools such as English proficiency, ethics and teamwork etc. were by far the most complex and difficult outcomes to instill into students and assessed. Hence, the Department leaned on the Faculty to deliver these outcomes via the general education courses as well as other activities and simply evaluate the outcomes sparingly according to the priority and needs (Maneeratana, Sripakagorn, 2009; Maneeratana *et al*., 2010).

Apart from the main course objective on problem formulation and approximation, the Statics, as the first line course in the vertical solid mechanics discipline, also responded to the demand from the program outcomes. In this case, the experiment and other skills were also addressed by the Statics project.

4.1. Experimental Skills

Students usually studied Statics in the third semester, before any of the 3 laboratory courses in the formal experiment stream (Pimpin, Maneeratana, 2010). In 2010, the discussion between the Statics and the experiment committee concluded that the skill that could be seamlessly introduced in the Static project was the measurement. Specifically, students had to start reporting the reading from analog displays to the nearest marked gradation or half point and clearly stated the reading error as half the resolution. The criteria were embedded into the item 2.1 in the scoring rubric (Table 2).

At the end of the course, the knowledge retention was assessed during the course evaluation. Students were casually asked to properly report a simple reading (Figure 3). The answers to the multiple choice question (Table 3) showed that while more than 70% chose the nearest marked gradation or at halfway between, more than half of those students still confused about the reading error.

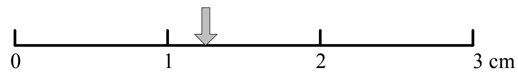

Figure 3. Question on reading still retention

Table 3. The percentage of students' answers on the reading skill retention

Answer List	2010 Class	2011 Class
1.0 cm ± ½ cm	26.1	29.6
1.2 cm ± ½ cm	15.2	16.9
1.5 cm ± ½ cm	0.9	1.1
1.0 cm ± 1 cm	40.3	39.7
1.2 cm ± 1 cm	13.7	9.5
1.5 cm ± 1 cm	3.8	3.1

4.2. Ethics

The plagiarism could be a problem of repeated assignments. In 2009, thanks to the introduction of grouping reports by types during the marking process, 2 reports were found to copy the same report from a previous year. With this lesson, subsequent reports were carefully checked against earlier documents in the years after and 4 reports plagiarized – 1 severe, 2 intermediate and 1 minor infringement. Most recently in 2011, a report was also caught to plagiarize at a very serious level.

This problem was considered a very grave issue; the plagiarism was added into the list of item that course had to address urgently. The primary response of the course management was to use a soft approach, combining exposing students to more information on plagiarism and other academic dishonesty as well as making them more aware of the sanction and punishment (Wan *et al.*, 2011). The offending students were interviewed, explained and advised individually about the misconduct and the punishment. In a broader view, they seemed to fall into the typical pitfall of either poor time management, resulting in a deliberate plagiarism, or unintentionally due to lack of reference and citation awareness. However, with the latest repeated offenses, less gentle responses had been considered.

Yet, it would be best if students were to understand and rectify their shortcoming before committing the deeds. The problem on referring skills was also further exacerbated from the removal of the dedicated 3rd year technical writing course, the main line of defence against such misconduct, in the newly revised 2011 curriculum. Due to the new regulation from the Ministry of Education concerning the minimum requirement for general education, the credits of the writing course under the direct responsibility of the Department were swapped to the general education under the English credit group (Pimpin, Maneeratana, 2010). This change did result in a huge workload reduction within the Department; nonetheless, the feedback and responds on this vital issue would be certainly decreased.

This made the action in the next semester when the students studying under the 2011 curricula would register for the course more significant. With fewer students, it would be possible to deal with the problem at a more manageable and individual level. A part of the strategy was to survey students' comprehension and opinions on the appropriate response so that the level of problem could be assessed.

Hence, at the end of the 2011 course, students were asked during the evaluation about their knowledge on the misconduct and the consequences. Five past or possible examples of plagiarism in the project reports were provided and students were asked to select the level of reprimand they thought appropriate. The given levels were (1) no misconduct, (2) misconduct, but no punishment, (3) some score deduction, (4) zero score for the project, (5) no project score with extra deduction, and (6) fail the course or more severe measure. The results in Table 4 clearly showed that students' knowledge and awareness on the consequences of plagiarism were much more lenient than in reality; the informing became the first priority thus.

Table 4. The percentage of students' answers on the plagiarism

Item	Appropriate Responses					
	(1)	(2)	(3)	(4)	(5)	(6)
1. Copy an earlier report with some changes	5.3	4.7	43.9	38.1	4.2	3.7
2. Use an earlier report in guide the analyses of the same structure	24.9	15.3	49.2	9.0	1.5	0.5
3. Use photo/images from web/catalogue without citing the source	20.6	22.8	52.4	3.2	0.5	0.5
4. Use a phrase from web or other sources without quoting	21.2	25.9	49.2	3.2	0	0.5
5. Modify a paragraph from web or other sources and cite the source	41.8	16.9	37.0	3.7	0	0.5

5. Students' Feedback

As the project had been but one of the options for the course objective, students' feedbacks on the project's merit would be very valuable. In the course evaluation, students were asked to rate their opinion on various aspects of the project. The 5-level Likert scales were (5) strongly agree, (4) agree, (3) neutral, (2) disagree and (1) strongly disagree. The answers were processed into a simple satisfactory parameter %sat as

$$\%\text{sat} = [\text{No. of (5) \& (4)}] - [\text{No. of (2) \& (1)}] / \text{No. of All Opinions} . \tag{1}$$

In all, 50% of students agreed that the project was useful and worthy of the efforts; the rest was neutral about the project with extremely few against. However, the utilization of the scoring rubric by students was not very extensive. This corresponded to the lack of self-marking in many reports.

Table 5. The percentage of 2010 and 2011 students' opinions on the merit of the project

Item	Year	Opinion (Agreement to Disagreement)						
		(5)	(4)	(3)	(2)	(1)	%sat	%sat
1. I was satisfied with the cross-section grouping and marking process.	2010	11.3	42.0	43.4	2.8	0	50.7	58.5
	2011	16.9	52.9	27.5	2.6	0	67.2	
2. I studied the marking rubric very carefully.	2010	5.7	33.5	56.6	3.3	0.5	35.5	32.3
	2011	12.1	33.3	37.6	12.1	4.8	28.6	
3. The rubric was a good method to mark the project.	2010	5.7	34.0	39.6	13.7	6.6	19.4	31.8
	2011	7.4	42.3	46.0	3.2	1.1	45.5	
4. The project helped me to understand the relationship between the theory and real life application.	2010	5.2	45.8	45.3	3.3	0	47.9	55.3
	2011	13.8	52.9	30.1	3.2	0	63.5	
5. The gained benefits from the project were worth the efforts and resources.	2010	6.1	42.5	47.6	3.3	0	45.5	48.3
	2011	10.0	45.5	40.2	4.2	0	51.3	

6. Conclusions

The paper based project in Statics was found to generally achieve the aim of increasing awareness of structures in daily life. Students had to view the environment in a new perspective and relate theory to practices. The rubric presented both advantages in terms of guidelines and relatively objective markings. However, it damped down the difficulty level of the problem and lacked the overall quality perception as items were marked as it they were entirely separated. Nonetheless, the unsophisticated problems might not be a bad news for most students. Even though the studied structures appeared to be too simple, it still provided a decent platform for leaning that ensured the minimum acceptable performances without too much burden on students.

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