Students Views on Engineering Mechanics Education and the Implications for Educators

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***Abstract**: This paper presents findings of a qualitative study conducted as part of a larger project to address the issue of high failure rates in first year engineering mechanics. Engineering student focus groups were held at two institutions, and were asked about the subject area, curriculum, and their approaches to study. Eight academics were also interviewed individually on the same topics to provide some context for the focus group outcomes. Documented responses revealed a tendency for both groups to focus on the most negative or extreme examples as cases which were representative of a wider situation. Although the focus group and interview protocols were designed to elicit positive and negative views, the negative appeared to dominate. We propose that the predominantly negative perception and interpretation of the situation, and an apparent 'us and them' mentality potentially contribute to high failure rates in engineering mechanics. These issues may be creating stumbling blocks, or leading to de-motivation in educators' attempts to teach the topic successfully, and students' efforts to learn the material effectively.*

Introduction

Why do so many students fail first year engineering mechanics? This is the question currently interrupting the sleep of a team of researchers from the University of Wollongong, University of Tasmania, University of Technology, Sydney, and the Australian Maritime College. The Engineering Mechanics (EngMech) Project is funded by the Australian Learning and Teaching Council and the EngMech Team is looking into the diverse range of influences leading to consistently high failure rates in engineering mechanics subjects, and what might be done about them. Failure rates in first year mechanics at the participating universities usually fall in the 20% to 40% range. To date, the approach taken by the EngMech team to investigate the problem of high failure rates in mechanics has involved a range of quantitative and qualitative research activities. We discuss a subset of the EngMech research in this paper: qualitative research into the causes of poor performance or failure in mechanics, as seen by engineering students and academics.

The literature on this topic contains a multitude of speculated causes of poor student performance in mechanics. We have summarised speculated causes elsewhere (Goldfinch, Carew, & McCarthy, 2008). While the causes cited in the literature were very useful, the researchers wanted to find out if these were apparent in all institutions (ie. ubiquitous), or if there were institution-specific issues causing difficulties for students. Moreover, it was necessary to find out if there were differences in how academics viewed the causes of poor performance, and how students viewed them.

The aims of this research were to:

- Document students' and educators' perspectives on what affected learning in mechanics.

- Compare and contrast students' and academics' viewpoints.
- Establish what issues were general, and which were institution specific.
- Discover potential causes of poor performance not previously considered by the EngMech team.

Method

This research involved two main components: Focus groups held with current or past students of first year mechanics at two of the participating Universities (Uni A and Uni B) and one-on-one interviews with academics who taught or tutored mechanics at Uni A. It is worth noting here that most of the EngMech team are academics who teach mechanics. As such it was crucial to design each research component to elicit *new* ideas on causes of student failure in mechanics, ideas independent of the EngMech researchers preconceived ideas and experiences.

Focus Groups

Focus groups were chosen as the preferred method of research for students for a number of reasons. Foremost of these was the students' position in the context of the university. There is potential for an educational researcher to be seen by students as something of an authority figure. Using focus groups positions the researcher as a minority in the group, decentering the role of the researcher and allowing the participants more opportunity to take the lead in discussion (Kamberelis & Dimitriadis, 2005). Secondly, focus groups allow a great degree of freedom on what issues are discussed and what points are raised. Students are enabled to express what is at the forefront of their (educational) experience, without being constrained to a framework of questions. Indeed, the use and running of these focus groups was a deliberate departure from researcher-led approaches such as paper-based surveys, which require a substantial degree of background knowledge (or perceived background knowledge) of the problem in order to pose appropriate stimulus for participants (Bouma, 2000). As the researchers had a strong interest in discovering what had not previously been considered, the freedom afforded to research participants through use of focus groups was of key importance.

The groups held at Uni A were self selecting which often resulted in a fairly homogeneous group of participants (a group of friends in some cases). The shared experiences and backgrounds of these homogenous groups can enable deeper discussion of the issues raised by way of a high level of familiarity between participants (Kamberelis & Dimitriadis, 2005). In a number of instances during the focus groups, participants talked though issues without the intervention of the facilitator, this was viewed as evidence of research findings that were in some ways independent of the facilitator. A downside of having self selecting groups at Uni A was the response rates. The broad announcement of the focus groups did not appear to strike a chord with many students, and the response rate at Uni A was very low. The invited focus groups which were run at Uni B enjoyed a much higher response rate. It would appear that the invitation approach encouraged more enthusiasm for the focus groups, than self-selection. Alternately, timing of the focus groups may have been better at Uni B, the student body at Uni B may have been more engaged, or students at Uni A might have been suffering survey overload.

Groups were limited to seven participants, plus the facilitator to allow all participants ample opportunity to respond in the one hour time allotted. Some focus groups were as small as two or three participants. It was evident that one hour was appropriate, though some groups ran slightly over time at the request of the participants. As the researchers were conducting exploratory focus groups, a low level of facilitator involvement was planned (Morgan, 1988). However, when groups numbered less than five, it was difficult to maintain discussion without facilitator involvement. Four focus groups were run at Uni A (eleven students in total) and two at Uni B (13 students in total).

Questions for the focus groups were a brief set of open-ended prompts. The prompts were ordered to focus attention initially on the course itself to give participants time to establish familiarity with the focus group setting. The prompts gradually moved toward more probing questions focusing on the students' behaviour and study habits. This approach was judged successful, as evidenced by most students offering their own grades to the group discussion by mid-way through the session

Academic Interviews

Semi-structured, one-to-one interviews (Kvale, 1996) were seen as the most appropriate method of surveying and probing academics' views on why student struggle with introductory mechanics. The flexibility in terms of scheduling one-to-one interviews was perhaps the foremost reason for selecting this research method. Interviews also mitigated a number of other issues previously encountered when gathering the views of academics. Among the participants were past, present, and future coordinators of the first year mechanics subject at Uni A, junior and senior academics, and a wide range of cultural and educational backgrounds. The one-to-one situation allowed each participant ample opportunity to express and justify their views. This was important, given the breadth of experience of some engineering academics, and the need to openly discuss political and hierarchical issues and the history of course structures and assessment.

Questions and prompts for the interviews were almost identical to those used in the focus groups, though reordered to focus first on student learning behaviors, and later on the way individuals taught and assessed mechanics. Each interview was audio recorded and the interviewer made notes during and after the interview to record and highlight key points emphasized by the academic.

Results: Student Responses

During each of the focus groups, students were unexpectedly forthright and articulate in their responses and little encouragement was required to get students to elaborate on their statements. In general, fruitful discussion was maintained for the duration of each session even in small groups (ie. two or three participants). Most groups were fairly homogenous in makeup, with domestic, full time, school leavers forming the majority of participants. This is unsurprising given this groups' dominance in the first year engineering cohort in each institution, however, greater consideration may be needed on how to capture the views of mature-age and international students.

In terms of specific problem topics in mechanics, few common themes emerged and the topics cited varied from person to person. This occurred at both institutions: *I think everyone had something a bit different actually* (Uni B). This reiterates earlier findings by the EngMech team quantifying the mistakes and misunderstandings apparent in student final exam transcripts in first year mechanics (Goldfinch, Carew, & McCarthy, 2009) where the mistakes made by individual students were quite diverse. Interestingly though, irrespective of what focus group participants nominated as difficult, there was general agreement that the engineering mechanics course content was relevant, useful and interesting: *I'm enjoying the content, like, I know it's something I'm interested in* (Uni A).

A second noticeable trend among participating students was an apparently limited awareness of the topics they had covered in first year mechanics. In the case of current students, course outlines were often referred to to establish which topics they had trouble with, while past students often had trouble recalling all the topics they had covered.

When commenting on their approaches to study, consistent themes emerged in each group indicating assessment-led study patterns, as described by Biggs (2003). It was apparent that many students preferred regular (weekly) assignments that enforced regular study. Frequent comments along the lines of *it's hard to keep yourself engaged in one thing when there's so many other things to do* (Uni A), and *yeah you're pretty much just trying to keep your head above water, you don't really have time to absorb it* (Uni A) supported the conclusion that students were predominantly concerned with assessment tasks over and above achieving deep understanding of the concepts in mechanics. It seemed that students' quests for marks may have been hindering their ability to learn and engage with their education effectively. There were a number of comments made by students suggesting that assessment tasks in one subject distracted attention from other subjects and hindered regular study: *You're sort of just going from one thing to the next trying to get as many marks* [as you can] (Uni A). For Uni A students, weekly assessments in two of their subjects often took precedence over study in the other two subjects (including mechanics) that had less regular assessment.

Some accounts of study efforts by students pointed towards ineffective/inefficient approaches to independent study. Students reported spending hours trying to solve textbook problems and ending up with little to show for their effort. This appeared to be disheartening, particularly when students

reported being unable to access assistance from staff when needed: *I even went to see one of the lecturers and he sort of made me feel like I shouldn't have gone to see him* (Uni A).

When considering factors outside the university setting that affected learning in engineering mechanics, the research revealed that there was little consensus among participants. Few considered socialising to have a great impact on their learning, with some student noting that they did not go out regularly during semester. Views on part-time work were divided. On the one hand students who did not work tended to believe full-time study did not allow for this: *when you're doing something like this you don't have time really for a job* (Uni A). On the other hand, students with part-time work indicated that working wasn't problematic: *I had too much time before…*(Uni A) and *I was getting bored so this is filling in my time* (Uni A). Indeed from these focus groups it seemed the impact (or potential impact) of part-time work may be being mitigated by the students themselves through their decision to work or not work. Closely related to this was the apparent stress caused by having limited funds: *sometimes it's hard to come up with $1.70 each way every day to get to uni* (Uni A).

In all of the focus groups there was a predominately negative attitude to many aspects of the way the mechanics subjects were run. The specific details of these are too numerous and convoluted to report in this paper. The facilitator noted, however, that comments and discussion relating to negative aspects of the course seemed more deeply considered than the positive aspects of the course. When asked to comment on negative aspects of the course, most students readily responded with personal experiences and stories they had heard from colleagues. Regardless of what caused this apparent negativity, it would appear that the negative experiences of learning in engineering mechanics, and university generally, were at the forefront of participating students' awareness. It is concerning that aspects of the courses under consideration that may have encouraged student motivation and engagement (the positives) were being overshadowed by factors that may de-motivate students (the negatives).

Participating students' ideas on what would be helpful in engineering mechanics were quite narrow in scope but had a high degree of consensus. Peer assisted study sessions or tutorials were raised in all groups at both institutions without suggestion from the facilitator. Plenty of worked examples were also suggested as very helpful. This was a fairly strong indication of what students found most useful within the scope of assistance with which they were familiar. Laboratories and site visits were also nominated as helpful for improving understanding of mechanics concepts. The limited range of ideas suggested by students was interesting; it seemed that the students were simply picking a 'best of' from the range of learning experiences and support they had previously encountered.

Responses: Academics

The engineering academics interviewed at Uni A during this study offered some interesting perspectives to contrast with the student focus group findings. An area where academics' responses bore striking similarities to those of students was the general focus on negative aspects of the teaching/learning process in engineering mechanics. Other areas raised by academics that concurred with student opinions recorded during the focus groups were:

- The volume of content in first year mechanics being too large and the pace of its delivery too fast.
- Students' apparent assessment driven approaches to study
- The perceived usefulness of peer assisted study in helping students to learn.

Over and above these points, the participating academics' united view on what caused students to perform poorly in engineering mechanics was students' poor attitudes and approaches to study. These attitudes and approaches were expressed by academics who were interviewed as attributes brought into the course at the beginning: *to some extent they want to be spoon fed the information* and *first year they are babies*. It is interesting to speculate on the reasoning used to support these assertions. Many anecdotes provided by interviewed academics appeared to focus on individual students or a very small group that, on the basis of further questioning, did not appear to represent the behaviour of the whole class. It is difficult to compare this situation with the data from the student focus groups as the students attending these appeared to be quite well engaged with their study. However, probing by the interviewer revealed academics acknowledged that 'very poor attitudes' were a problem only for the minority of students. The overemphasis by academics of this as a causative factor may be an example of a focus on the most negative cases: in this case, the most disengaged students. Perhaps this focus on

the negative is unsurprising. When asked about the positives in the mechanics course, it was clear the academics interviewed did not regularly receive positive feedback like that presented by students during the focus groups. While there were numerous positives to report from the students' perspective, it appeared Uni A and Uni B had limited formal procedures for relaying this back to academic staff.

More specific issues nominated by academics as impacting engineering mechanics education included: students' background in mathematics and physics; and general high school performance as measured by University Entry Rankings. At the topic level, similar to the focus groups, there were a wide variety of topics reported by the academics as causing difficulty for students.

Other outcomes of the academic interviews relating to course design are somewhat more difficult to report. Views on how the material should be delivered, how the subject should be structured, and how it should be assessed differed greatly between the academics interviewed. The diversity here may have been more a function of the diverse backgrounds of the group of academics interviewed. Rather than reporting the specific areas of disagreement here, it may be more useful to consider the implications of this diversity of views for the teaching and learning of mechanics.

Analysis and Interpretation

The key research question: 'why do so many students fail first year engineering mechanics?' is illuminated by the research reported here, but is not answered in a definitive way, or with consensus. There was no single topic that all students nominated as challenging; this suggests that improving the success rate of students is unlikely to be achieved by focusing on particular components of the course material. The findings indicated that focusing on overall study and teaching techniques may be more valuable. For example, accounts of students having inefficient approaches to independent study suggested academics might concentrate on working with students to develop more effective learning approaches. The transition from school to University is a major step for many students, with University teachers expecting a more independent approach to learning. First year students may need explicit instruction in a range of effective study techniques. One study method which received support from both students and academics was peer assisted study groups or tutorials. While it would be naïve to assume that a single technique will address all problems faced by students, greater resourcing of peer assisted study groups may be warranted for addressing high failure rates in mechanics.

The diversity of responses to a number of questions posed during this study suggests the educational techniques being commonly utilised in first year mechanics may fail to account for the breadth of motivational switches, personal circumstances and learning styles of students. Whilst there was diversity in academics' responses on how best the course should be taught, individual academics often teach according to their own individual frameworks or experiences of being taught (Biggs, 2003). The concern with this is where a learning style mismatch may leave some students struggling for both motivation and success (Felder & Silverman, 1988). Broader approaches to teaching and learning in individual mechanics courses may provide benefit through improved student enthusiasm and performance, and engagement across a wider range of student motivations, circumstances and styles.

Findings on assessment show this is another area for potential impact on study failure rates and study habits. It may be hard to move students away from having study patterns which are assessment led and driven, but this could be used to the advantage of the academic. Focus group findings suggested that the design and pacing of assessment tasks in other first year subjects were driving students to keep up with learning in those subjects. This is a pattern which might well be replicated in mechanics.

A theme that emerged from the EngMech research on student and academic perceptions of mechanics teaching was negativity: negativity from students to many aspects of the way the mechanics subjects were run, and negativity from academics to students' attitude and approaches to study. There was clear disagreement documented, with students and academics tending to implicate the approach of the other community. No one side of this apparent disagreement is likely to be completely right or completely wrong, the answer to improved student learning is probably somewhere between the two perspectives. Therefore to improve the situation students may need to take more ownership of their learning techniques, experiment with different methods and work towards developing study methods that are

effective for them individually; whilst academics could contribute to the process by broadening out their teaching approach to allow for the diverse learning styles of students.

It is worthwhile focusing on the positive responses from the focus groups conducted during this study. In particular there was general agreement from participating students that the content of mechanics courses was relevant, useful and interesting. This is a fundamental result and it is perhaps somewhat surprising that given this interest in the content there was so much negativity expressed about other aspects of mechanics courses. This enthusiasm could be used as a foundation for improving overall student passion for studying first year mechanics; making the connection between the fundamental concepts of mechanics and learning for deep understanding would be key.

Conclusion

The research discussed here has provided interesting insights into the experiences of teaching and learning mechanics for students at two universities, and academics at one university. The principal findings were: the negative focus of students and academics; diversity of views on the most difficult topics; and the broad scope of issues contributing to high failure rates. The research exposed several avenues for further research including: the appropriateness of self-selection in recruiting focus group participants; the minimum effective level of facilitator involvement in running focus groups; and the potential of focus groups for assisting students to refine their approaches to study.

In the EngMech team's endeavour to discover something new, it was demonstrated that even a seemingly homogenous group of students have diverse learning needs. From this we conclude that greater co-ownership of curriculum is required and a greater range of teaching approaches may be needed for first year engineering mechanics. This research also demonstrates how qualitative research offers a useful avenue to improve understanding and communication between students and academics.

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