Basic Mechanics: Learning by Teaching – an increase in student motivation (a small scale study with Technology Education students)

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Abstract - This paper discusses the introduction of peer learning and teaching into the Basic Mechanics course of a Technology degree. Statics was taught conventionally using lectures and tutorials. Dynamics was taught using the premiss "Tell me and I forget; show me and I remember; involve me and I understand" as an educational principle. The students worked in small groups and were asked to learn agreed topics by teaching them to other groups of students. The course was extensively evaluated and 82% said they enjoyed the dynamics part of the course. When checking the results there was no significant difference between the raw scores obtained in either the statics or dynamics exam for the females and mature males, but when the scores of the males aged 20 or less were also included a significant difference (p<0.05) between the exam scores appeared. 83% of the young males scored considerably higher in the dynamics exam. There was roughly an equal number of males aged 20 or less, females and mature males in the class. This is the completion of a work in progress paper given at FIE2003.

Index Terms – Basic mechanics, peer learning, peer teaching, student motivation.

INTRODUCTION

The basic mechanics class where this teaching intervention took place is part of the Technology programme for the Bachelor of Technological Education (BTechEd) Degree established at the University of Glasgow (Scotland, UK) for supplying teachers of technology for Scottish schools. The school subjects that the students are preparing to teach are Craft & Design, Product Design, Graphic Communication, Practical Craft Skills and Technological Studies. It is for Technological Studies that students need an understanding of the basic concepts of mechanics. The entrance qualifications of the students vary from those having completed post school Certificates or Diplomas (HNCs or HNDs) in engineering subjects to school leavers only having studied the Craft & Design or Graphic Communication courses, neither of which have any requirement for any skills or understanding in maths and science. As the subjects taught in school technology departments are so diverse the continued insistence of mathematics and a science (normally physics) as an entrance qualification for school leavers was too restricting, and students who would have made very good teachers were being denied the opportunity to teach technology. Most mature students typically join the course with post school qualifications in an engineering discipline but increasingly we are receiving applications from students with a design or skills (carpentry) background. The entrance qualifications were relaxed several years ago and the first year mathematics course has been adapted to allow students to learn and be assessed at their own pace [1]. In order to accommodate the greater variety of students and also reduce the overall workload in first year the Basic Technology course was split into its component parts of Electricity and Electronics which was kept in first year and Mechanics which was moved to the second year. This took place in session 2001/2002. The first year electricity and electronics course also assumes no knowledge of the subject. Other students who are not part of the BTechEd degree but taking the technology courses also took part in this study.

Mechanics can appear to be a very dry subject when taught through lectures which is predominantly the case in higher education. Students learn to apply formulae to solve problems and often do not appreciate or understand the underlying concepts because these may be at variance with their experience of the world around them [2]. The educational intervention that is presented in this paper is a small scale case study loosely based on Conversational Learning as proposed by Pask [3] along with the ancient Chinese proverb, “Tell me and I forget, show me and I remember, involve me and I understand”. The course involved the students in both peer teaching and peer learning. Most students (82%) found this method of learning enjoyable and there is evidence that in this class it increased the motivation to learn in young males. This learning intervention was originally presented as a Work in Progress paper at FIE2003 [4].

METHODOLOGY

The course under consideration is an introduction to basic mechanics presented to the students in the second year of the
degree programme in session 2002/2003. In order to investigate the effects of the teaching intervention the two main areas of mechanics, statics (mechanics of structures, study of stationary objects) and dynamics (study of objects that are moving) were treated differently. Peer learning and tutoring was introduced into the dynamics part of the course while statics was taught using traditional lectures and associated tutorials.

Only the examination scores for the two parts of the course were compared with each other and also with the scores of another cognate subject, electronics, taught to the same students. The electronics is predominantly a workshop based course. The overall exam scores for mechanics for the previous session (2001/2002) are also presented.

I. Course procedure

At the first class meeting the operational procedure for the course was outlined to the students by explaining that the two parts were to be delivered differently. That statics was to be taught using lectures and tutorials whilst the dynamics was to be delivered concurrently via workshops. The author then discussed with the class which topics in dynamics were going to be covered. Those students who had already studied some mechanics and felt sufficiently confident about their knowledge were asked to lead or join a group. Eight groups were formed and the remainder of the class were split randomly between the groups. In order to engage the students and encourage them to take responsibility for their own learning each group was asked to suggest a list of topics that they thought should be included in a basic mechanics course. A complete list was finally prepared which included most of the topics that would normally be covered in such a course for technology students. The list, for the dynamics part of the course, was organised into the following four collections of topics:

- velocity, acceleration, distance/displacement, linear motion, time (including examples such as projectile motion).
- levers, gears, pulleys, rotary/angular motion, torque and could also include circular motion and moments of inertia.
- Newton’s Laws, force, mass, weight, momentum and impulse.
- work, power, energy including elastic energy and could also include Simple Harmonic Motion (SHM).

Each group was randomly given one set of topics to study, thus each set of topics was studied by two groups. The groups were allowed seven 2 hour timetabled sessions to learn and prepare teaching material to enable them to present it and discuss it with another group.

The following resources were suggested to help with their learning: textbooks for reference; videos; computer packages; various pieces of kit; and the World Wide Web. Two fourth year students, acting as tutors, and myself were always available in class to help with any problems and explain concepts to groups if difficulties arose. All handouts and teaching materials produced by the groups were checked for relevance and accuracy.

During the second and third terms each group of students had the opportunity to discuss and teach their topic to three other groups, and they also had the opportunity to learn about the three topics they had not studied. Four concurrent discussion/teaching sessions took place in separate classrooms in small groups, and, by completing a questionnaire, the students were required to reflect on each of the sessions immediately following them.

At the end of the course the students had a debriefing session on the peer learning and teaching and then a final anonymous feedback session which included the whole of the mechanics course – the statics and the dynamics.

The assessment for the whole course was split 50:50 between statics and dynamics. The statics part was divided between exam questions worth 40%, and an individual assignment worth 10%. The statics part of the exam contained 7 questions and the students had to choose 5. The dynamics was broken down to 20% for examination questions, 20% for the group working, preparation and teaching part of the course and 10% for submission of an individual log book. Each group of students was required to prepare examination questions on their topic, and the dynamics part of the final exam included one compulsory question prepared by the author and six exam questions, based on the students’ ideas, of which they were required to answer three. The final examination, which contained questions from both parts of the course, was three hours long.

II. Participants

A class of 33 students took part in this teaching intervention 26 of whom were studying for the BTechEd degree and the remaining 7 were studying for another Technology based degree. The class could be split into three distinct groups, 10 females, aged 21 or less (young females), 13 males aged 21 or less (young males) and 10 males aged 22 (24 - 47) or more (mature males).

The students joined the university with a diverse range of entry qualifications, and appreciating this is important when discussing the results. Of the 10 young females 6 had no technology background, five of the 13 young males had no technology background and among the mature males 3 had no technology background and entered the degree on the Scottish Wider Access Programme (SWAP) which provides mature students with an entrance qualification for higher education.

DATA COLLECTION

The data collected as part of this case study was regarded as the evaluation of an educational intervention introduced into a degree programme. No control group was considered because of the ethical implications.

As this was the first time the course was delivered in such a manner, it was very carefully monitored and evaluated throughout the session. A considerable amount of quantitative and qualitative data was collected using questionnaires, confidence logs, tests, focus groups, feedback sessions, reflective journals and the results of the examinations and assignments.
This paper concentrates on the quantitative data collected from the end of course examination scores only and not the results of any of the assignments. Data were analysed using SPSS version 10 and the graphs created using Microsoft Excel.

Comparison with the examination results from the previous year was not possible because there was no breakdown between the statics and dynamics scores and the membership of the class was quite different. There were only 4 young males, 8 mature males, 9 young females and one mature female. The course was taught by two lecturers who were different to the lecturer who delivered both parts of the course being evaluated here. Means for the whole course, however, can be seen in Table I.

A comparison has also been made between the two parts of the mechanics courses and another cognate subject taken by the same class, electronics, also a workshop based course, using the same cohort of students.

**PRESENTATION OF EXAMINATION RESULTS**

Table I shows the means and standard deviations for the statics and dynamics parts of the examination for the whole class and also for the three groups: young males; young females; mature males.

<table>
<thead>
<tr>
<th>Results in percentages</th>
<th>Elect - Year 2</th>
<th>Mech - Statics</th>
<th>Mech - Dyn</th>
<th>Mech - Total</th>
<th>Mech - Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Session 2002/2003</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Whole class</td>
<td>45.4</td>
<td>35.9</td>
<td>59.8</td>
<td>47.9</td>
<td>49.3</td>
</tr>
<tr>
<td></td>
<td>sd 13.9</td>
<td>sd 19.2</td>
<td>sd 17.8</td>
<td>sd 14.6</td>
<td>sd 37.7</td>
</tr>
<tr>
<td>Young males</td>
<td>66.3</td>
<td>51.0</td>
<td>48.9</td>
<td>40.1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>sd 13.9</td>
<td>sd 11.1</td>
<td>sd 11.2</td>
<td>sd 17.6</td>
<td></td>
</tr>
<tr>
<td>Young females</td>
<td>64.1</td>
<td>61.8</td>
<td>61.9</td>
<td>53.3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>sd 15.4</td>
<td>sd 22.4</td>
<td>sd 19.0</td>
<td>sd 17.3</td>
<td></td>
</tr>
<tr>
<td>Mature males</td>
<td>64.0</td>
<td>61.8</td>
<td>61.9</td>
<td>53.3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>sd 19.8</td>
<td>sd 22.4</td>
<td>sd 19.0</td>
<td>sd 17.3</td>
<td></td>
</tr>
<tr>
<td>Have some technology</td>
<td>64.6</td>
<td>64.1</td>
<td>60.1</td>
<td>48.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>sd 19.8</td>
<td>sd 17.6</td>
<td>sd 15.4</td>
<td>sd 27.0</td>
<td></td>
</tr>
<tr>
<td>No technology</td>
<td>59.3</td>
<td>49.0</td>
<td>42.0</td>
<td>44.6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>sd 23.0</td>
<td>sd 14.5</td>
<td>sd 10.0</td>
<td>sd 16.1</td>
<td></td>
</tr>
</tbody>
</table>

Means are also shown for students who have some technology background, either Scottish Higher Physics, Higher Technological Studies or post school qualifications (ONC, HNC, HND), compared with those students who have no background. The means and standard deviations for the total exam scores for the two consecutive sessions 2001/2002 and 2002/2003 can be also be seen. As a comparison the means for the second year electronics course is also included.

**DISCUSSION OF RESULTS**

When looking at the overall examination results it must be noted that Basic Mechanics is only first introduced into the second year of a degree programme which has a very broad content including drawing, design, craft skills and education as well as the technology subjects. The students were introduced to Electronics in their first year so were already familiar with it.

A paired t-test was performed on the statics and dynamics exam scores for the whole class and there was a significant difference at the 5% level between the means of the two scores ($t = 2.647$, $df = 32$, $p < 0.05$, two tailed). When the same test was performed on the scores obtained by the young females and mature males only, this significance disappears ($t = 0.469$, $df = 19$, $p = 0.645$, two tailed), thus suggesting that the results from the young males caused the initial significance. The student numbers for the young male group are too small to carry out any other meaningful statistical tests and only trends may be observed by looking at the raw data – see Figure 1.

**Comparison of Statics and Dynamics Scores for Young Males**

For the young males the mean exam scores for statics, dynamics and electronics are 35.9%, 59.8% and 45.4% respectively. So as a group they performed poorly in statics, a little better in electronics and reasonably well in dynamics. Seven of the 13 students joined the degree programme with...
Higher Physics and one student gained a grade A in higher Technological Studies, so 5 students (1, 2, 5, 8 and 12) had no technology background at all.

Only one student (no technology) got less than 40% for dynamics, the other 12 students all scored more than 40%.

Also from the figure it can quite clearly be seen that 8 students gained less than 40% for statics including all the students with no technology background. All but 2 of the students performed better in dynamics than statics, and of those the one with no technology background performed poorly in both statics and dynamics but passed electronics with 46.7%. Another student with no technology background got the third highest score in the whole class for dynamics (82.5%) whilst only managing 15% for statics. He did not sit the electronics exam at all.

To sum up: the marks for statics and dynamics for student 1, the lowest scores for the whole class, are within 10% of each other; the statics score for student 6, who has the highest statics score in the group, is more than 10% greater than the dynamics score; the other eleven students’ dynamics scores are all more than 10% greater that their statics score.

II. Young Females

For the young females the mean exam scores for statics, dynamics and electronics are 46.7%, 51.0% and 66.3% respectively. All the females scored more than 40% for the dynamics exam and the student with the highest mark among the females was a direct entrant into second year after having completed the first year of a mechanical engineering degree. Only four of the students began the degree programme with any technology background and one of them failed to gain 40% for the statics exam. Three of the 6 students (1, 2, 5, 7, 8 and 9) with no technology background gained 41.7%, 60% and 75% for the statics exam whilst the other 3 gained less than 40% - see Figure 2.

To sum up: the marks for statics and dynamics for three students are within 10% of each other; two students’ statics score are more than 10% greater than their dynamics scores; the other five students’ dynamic scores are all more than 10% greater that their statics score.

II. Mature Males

For the mature males the mean exam scores for statics, dynamics and electronics are 62.0%, 61.8% and 64.1% respectively, which are very similar. From Figure 3 it can be seen that two students gained less than 40% for dynamics and one student gained less than 40% for statics. The student with the highest mark in statics joined the degree with an HNC in Civil Engineering. Students 2, 3 and 4 joined the course with no technology background and student 1 with the poorest score has an HNC in Electronics and his score for the electronics exam was 67.5%.

To sum up: the marks for statics and dynamics for four students are within 10% of each other; four student’s statics score are more than 10% greater than their dynamics scores; the other two students’ dynamic scores are more than 10% greater that their statics score.

Overall the students performed better in both the dynamics and electronics than the statics. When looking at the individual groups a slightly different picture emerges. The mean scores for the mature males are similar (between 60% – 65%) for all three courses which is not unreasonable as 7 out of 10 have some technology background. The students with no technology background had the most difficulty and performed slightly better in the electronics exam, but this is their second year of studying electronics. There is no evidence that different methods of teaching have any direct impact on the students’ learning. Our perception to date has been that most mature students are highly motivated learners. They have often given up a job and have had to make financial sacrifices to enable them to complete the four year degree programme, and will do their best whichever way a course is taught. However, the students appeared to perform better overall in mechanics than in the previous session where 6 of the 8 mature males had a technology background.
The young females have the fewest students with a technology background of the three groups and the mean scores show that they performed slightly better in dynamics than statics but much better overall in electronics. It is not surprising that the young females performed less well in the mechanics than the mature males because the males have a much stronger technology background. The females did, however, perform at least as well as the mature males in electronics. Again this is possibly because they studied electronics in the previous year and were more comfortable with the subject and familiar with the terminology. There is some evidence that the method of teaching dynamics may have benefited the females as they all gained more than 40% for the dynamics exam whereas four of them scored less than 40% for the statics exam. Our experience with the young females is that they are usually keen, work hard and often perform very well in group activities. Inspection of the overall means for both sessions indicates that the females, most of whom had no technology background in both years, performed better in the second session.

The mean scores show that the young males performed considerably better in the dynamics than both the statics and electronics courses. Sixty-two percent of the group have either Higher Physics or Technological Studies, where some mechanics, particularly kinematics and mechanisms, and a substantial amount of electronics is covered. It would have been reasonable to expect the performance, particularly of dynamic and electronics, to be similar. As all but two of the students scored over 10% more in the dynamics exam than in the statics exam the evidence would suggest that the method of teaching the courses did influence the learning of this group of students.

Comparison of this group of students with previous session’s results is not very meaningful because there were only four young males on the course.

The other variable considered in this paper is the effect of entrance qualifications. When comparing the mean scores for students with and without a technology background, those without a technology background clearly performed better in dynamics than statics. Their best score, however, was in electronics which again may be due to familiarity. The method of teaching seemed to have little effect on the scores of the students with a technology background, but may have helped students without a technology background.

From the foregoing discussion it would appear that the teaching intervention particularly benefited the young males, and to a lesser extent students starting the course with no technology background. In the statics course students could choose whether or not they were going to put in extra work outside classes to develop their understanding of the topic. Although there were tutorials and formative assessment throughout the year there was no requirement to participate unless they wanted to learn and no continuous assessment was carried forward towards the final course mark. There was a small assignment that was submitted at the end of the year but that was only worth 20% of the final statics mark.

In the dynamics part of the course the whole teaching and learning process depended on group interaction and all students were required to participate fully. Each group had a mix of mature males, young females and young males. They were required to participate in the learning process otherwise it affected their overall assessment from an early stage in the course. This meant that the young males could not avoid working on this part of the course if they wanted to pass the course. It was not possible to revise at the last minute. The examination scores for them bears out the fact that they obviously had to put in extra effort for dynamics and as a result they performed better.

The mature males and young females probably put equal effort into both parts of the course resulting in less of an obvious disparity between the two scores. Had the dynamics course been easier than the statics then perhaps the mature males and female students would also have performed significantly on the dynamics part of the course.

Eighty-two percent of the students said they enjoyed learning this way. The six students who said they did not like the course consisted of three young females, none of whom had any technology background and three young males, one with no technology background and two with Higher Physics. All the mature males said they enjoyed the course. Student 1 of the young males whose performance was worst overall for the whole class did not enjoy the course, the other two students 9 and 11 both did much better in the dynamics part of the exam than the statics. Student 1 of the young females, who gained a similar score in both statics and dynamics said she did not enjoy the course. The other two young females were students 7 and 9. Student 7 did much better in dynamics than statics and student 9 gained a similar score in both. There is no evidence from this small sample to suggest that disliking the teaching and learning method had any real effect on the students’ final exam score.

CONCLUSION

Although the number of students in each of the three groups in the class is small and, therefore, not large enough to be able to carry out a meaningful statistical analysis, there do appear to be observed trends. Past research has shown [5] that the younger age group (18-20 year olds) tends to take a more surface approach to learning than mature students. There is also evidence from the same source that females demonstrate a stronger deep approach to learning than males. The findings in this small study would support both of these claims.

By increasing the pressure on the young males to perform, they have actually scored much higher in the assessment than they probably would have done otherwise. The author would not necessarily suggest that the particular method chosen here for teaching the dynamics course was the sole factor in increasing motivation in the young males, but any method which required students to work steadily throughout the year and co-operate with other students may well have a similar effect.
There also does not appear to be any clear evidence to indicate that liking or disliking the teaching and learning style affects the students’ exam performance.

When the course was originally prepared and delivered the main objective for the author was to investigate an interesting and stimulating way of encouraging students to take responsibility for their own learning and also develop a real understanding of the basic concepts in mechanics. “Having to explain some of these concepts to someone else highlights ones own understanding or misunderstanding of the topic”.

The aims of the course evaluation were to make sure that the students had learned something by this method of teaching and had not been disadvantaged by the experience. The improvement in scores for the young males only appeared on closer scrutiny of the examination results and it was not an original aim of the course delivery. The course was delivered in the same manner in session 2003/2004 and a comparison between the results of the these two years is underway at present.

REFERENCES


