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Enhancing the engineering students' confidence using interactive teaching methods – Part 1: initial results for the Force Concept Inventory and confidence scoring

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ABSTRACT: An essential goal of engineering education is to educate students who have a sound knowledge of relevant engineering subjects and are able to reliably evaluate what they know and what they do not know. Further, they should have a sufficient self-directed learning readiness. This encompasses awareness of one's learning needs, the ability to choose what learning methods and strategies to enforce and the ability of self-assessment when evaluating the outcome of one's learning activities. In order to gather more information about students' initial knowledge of basic mechanics and their confidence of their answers being correct, the authors developed further the well-known Force Concept Inventory (FCI) by including a grid in which students were asked to evaluate their confidence. The results of the FCI were well in line with other published results. There were no big differences between male and female students in the FCI results.

CONFIDENCE

The engineering profession is such that engineers should be able to reliably evaluate what they know and what they do not know and be realistic about their skills. One essential goal in engineering education is to increase the students' self-directedness. This goal is important in the context of life-long learning. The concept of self-directedness encompasses awareness of one's learning needs, the ability to choose what learning methods and strategies to enforce and the ability of self-assessment when evaluating the outcome of one's learning activities [1][2].

Studies show that students' academic performance, choice of career and retention in science and engineering programmes are influenced by their motivational beliefs and self-perceptions. Although it has been demonstrated that positive self-perceptions and motivation have an impact on students' success, there are very few studies on how teaching practices influence students' self-perceptions and motivation [3].

According to many studies, freshmen female students do not believe so much in their abilities to succeed in engineering subjects compared to their male freshmen counterparts. Although women have succeeded in their studies, they can be less confident than men. The difference in confidence can be so clear that men who have not succeeded in graduating in their engineering programmes are nevertheless more sure of their abilities to succeed in engineering than are women who have graduated. It can, of course, be speculated that male students are overconfident and that female students merely have a more realistic view of their abilities [4][5].

Female engineers who have made a career in engineering have been asked to reflect on their study experiences and profession [6]. Such qualities as self-confidence and good communication skills were rated as important for professional success and advancement. Many would have appreciated more academic advice and better support and encouragement from their instructors. The lack of sufficient opportunities to apply theoretical and technical knowledge was also frequently mentioned as having been detrimental to their education [6][7]. However, the authors feel that opportunities to apply technical knowledge and possibilities to do more hands-on experiments will benefit both male and female students. Today's engineering students have less experience in manipulating technical equipment, having spent greater time working with their computers.

The aim of this research is to investigate students' initial knowledge of basic mechanics and their confidence of their test answers being correct. The differences in confidence between male and female students were also studied. Students took the Force Concept Inventory (FCI) [8][9]. This was complemented with a grid for confidence evaluation when entering their engineering studies. The second part of this research focuses on how the application of interactive teaching methods and a conceptual approach influences students' learning and their level of confidence.

SUBJECTS AND WORKING MODE

The subjects of this study, 107 students, 56 female and 51 male, were all first year engineering students at Tampere Polytechnic, Tampere, Finland [10][11]. Students studied in different study programmes, including electrical engineering, chemical engineering and textile technology. They were studying their general professional studies, such as physical sciences and basic engineering subjects, and were taking part in their first physics course called *Mechanics 1*. The course dealt with kinematics, dynamics, the work-energy principle and the impulse-momentum principle of translational motion.

Students' educational backgrounds varied to some extent (see Table 1) and students were divided into three groups on the basis of their educational backgrounds. Students in group 1, consisting of 44 students, had studied at a vocational school, having a very limited education in physical sciences, including physics. Students in groups 2 and 3, consisting of 61 students altogether, had studied in upper secondary school. Students with upper secondary school background were divided into two categories. Students in group 2, consisting of 39 students, had studied only a few courses in physics, ie less than six courses, typically only one, which is the mandatory amount of physics courses in the Finnish educational system. Group 3 consisted of 22 students who had taken six or more courses of physics in the upper secondary school. The background studies of two students remained unknown. Students in group 2 were considered to have a modest background in physical sciences, while students in group 3 were seen to be familiar with the subject.

Table 1: Student's groupings by their educational background.

	Female	Male	Total
Group 1	11	33	44
Group 2	31	8	39
Group 3	12	10	22
Unknown	2	0	2

At the beginning of their physics course, one student group (chemical engineering) was asked about their ideas concerning physics teaching, how they had been taught earlier and how they would wish that they be taught in the future. Students expressed that physics teaching should be practical, things should be visualised and elucidated, examples should be used and they should be interesting. They wanted the lecturer to make physics interesting.

Interactive teaching methods, such as asking questions frequently, peer interaction [7][12], demonstrations combined with peer interaction and the PDEODE (Predict-Discuss-Explain-Observe-Discuss-Explain) working method were used [13][14]. Pre-lecture assignments were also utilised [7][15]. The lecturers teaching the *Mechanics 1* courses were particular about giving students the feeling that their learning is important. They consciously used qualitative approaches when teaching new phenomena and quantities. This also meant a frequent use of White's elements of memory, such as episodes, images and cognitive skills [16][17]. In addition, one student group (chemical engineeirng) was given the opportunity to undertake the Felder-Soloman Index of Learning Styles test [18] and Guglielmino's self-directed learning readiness test [1]. Students were given their test results along with feedback and a tutoring session on learning styles and strategies, as well as on self-directed learning readiness.

From the authors' points of view, using peer education and other interactive teaching methods, including the PDEODE method, can be seen as a challenging but rewarding experience. A very important enhancement is the increase of student activity during lectures. Some criticism will probably be observed and students will complain because they do not get the correct answers immediately and they will have to think on their own.

FORCE CONCEPT INVENTORY AND CONFIDENCE

The authors used the Force Concept Inventory (FCI) developed by Hestenes et al [8][9]. This test is frequently used to assess students' understanding of basic concepts in Newtonian physics (classical physics) [19]. The test includes 30 multiple-choice questions that cover force and relating kinematics. The authors wanted to gain more information about students' knowledge in physics and to see how confident students were of their chosen answers being correct. Thus, the authors developed the FCI further and included a grid in which students were asked to evaluate their confidence when choosing their answer alternative (see Figure 1). Students evaluated their confidence in every question using a scale from one to four (1 = very unsure, a mere guess; 4 = absolutely sure).

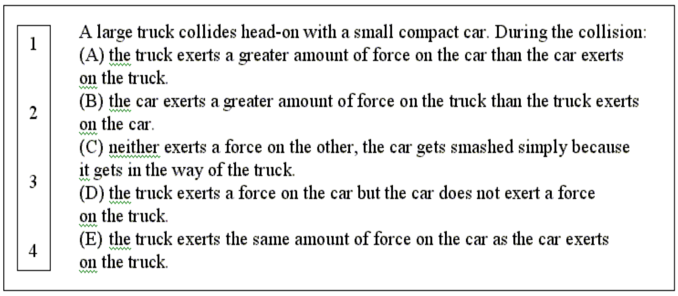

Figure 1: Question 4 in the Force Concept Inventory (FCI) [8][9]. Students evaluated their answers being correct by using a confidence scale from 1 to 4, where 1 = very unsure and 4 = absolutely sure.

Students were first asked to choose the correct alternative to the question and circle it. They were then asked to evaluate their confidence of their answer being correct by circling one of the numbers (from 1 to 4) in the confidence grid.

Students took the test during the second lecture of their physics course, *Mechanics 1*. Students were given ample time (one hour) to take the test. The lecturer motivated students to make a serious effort when engaged in their test, but assured them that the test results would not affect their grades. The aim of the test was merely to improve teaching and learning. The test, the test results and the broad scope of the results were discussed with students the following week, but the correct answers were not given. Students had the possibility to work on some of the questions in pairs and small groups, and present their solutions and reasoning. Some topics of the FCI would be dealt with in more detail later in the course.

RESULTS AND DISCUSSION

The results of the FCI are shown in Figure 2. These are in line with previously published results. In the figure, it can be seen which questions were especially difficult for the students and which questions they were unsure about despite their correct answers. This, no doubt, helps the lecturer in planning his course, making priorities and choosing his teaching methods.

Figure 2 shows that more than 50% of the responding students gave the correct answers to questions 3, 6, 7 and 19. Of these correct answers, over 50% were given with a confidence rating of three or four. These questions dealt with problems where the path of an object was studied and gravity was assumed to be nearly constant. Major difficulties were observed in questions 5, 18, 26 and 30. This result verifies that the initial thinking is deeply rooted and that students do not have a clear understanding of Newton's first law. This has to be carefully taken into account when teaching physics and related subjects, such as statics, dynamics and constructional subjects.

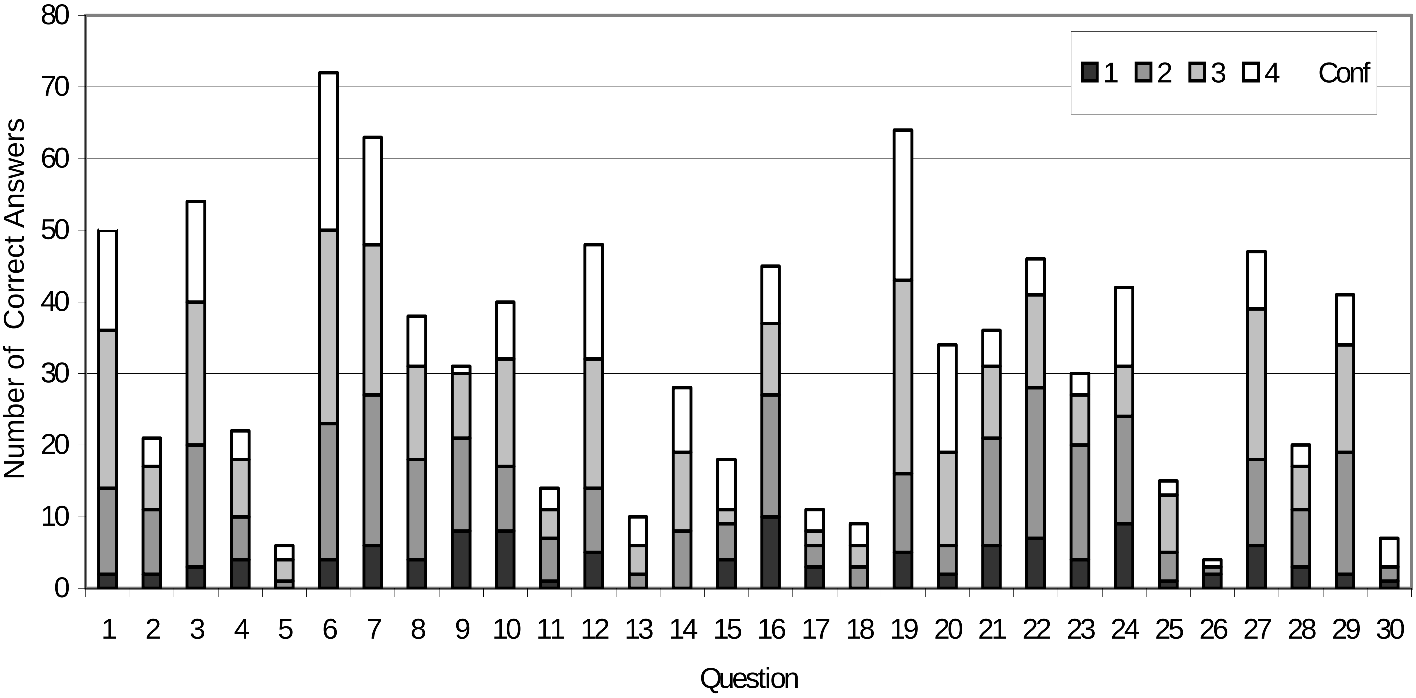

Figure 2: Students' confidence in case of correct answers in the FCI.

Twenty-two students gave the correct answer, *E*, in question 4 (Figures 1 and 2), while 85 students gave the answer A, which was incorrect. The total amount of answers given was N = 107. Of all the students who had answered the question correctly, only four were confident about their answer, circling the four in the confidence grid. Alarmingly, 26 students who chose the incorrect alternative, *A*, gave a confidence evaluation of 4 (absolutely sure).

When the lecturers reflected on what the reasons were for students having chosen their alternatives, their pedagogical content knowledge, no doubt, increased. They have to ponder if the reason for the incorrect answers is merely the *dominance principle* [20]. Or there may be some other reasons that may be found. It is also necessary to reflect on the kind of learning results and conceptions if the focus of the issues dealing with question 4 is not on the deeper understanding of Newton's first and third laws. What is the forecast if such misconceptions prevail? Can the learning of statics and dynamics proceed, and can this lead to true understanding and to skilful applications of the basic principles of Newtonian mechanics? Or must we, as educators, confine ourselves to mere rote learning and routine calculations?

The confidence distribution of all answers for both female and male students is illustrated in Figure 3. It is noted that the male students in the survey had a slightly better reliance on their own abilities than the female students.

In investigating the confidence scores with regard to educational background (Figure 4), only very slight differences between students who entered their engineering programmes through a vocational route or through a high school route were detected. The number of physics courses that students had studied before entering the Polytechnic and taking the FCI does not seem to have had a big influence on their confidence either.

Interestingly, when the confidence distribution of the correct answers is examined, the margin between the male and female students grew (see Table 2 and Figure 5).

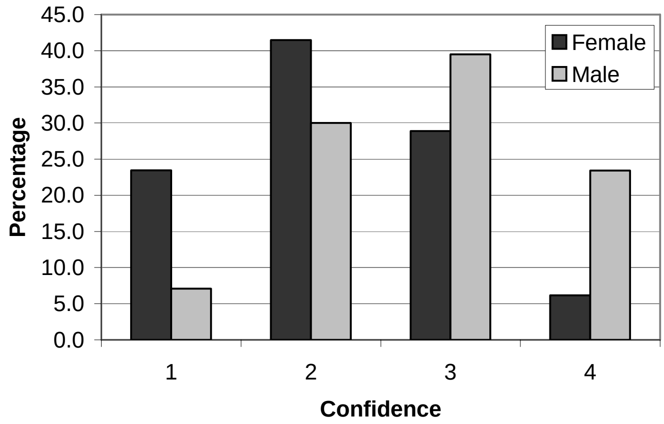

Figure 3: The confidence distribution of all the given answers by gender.

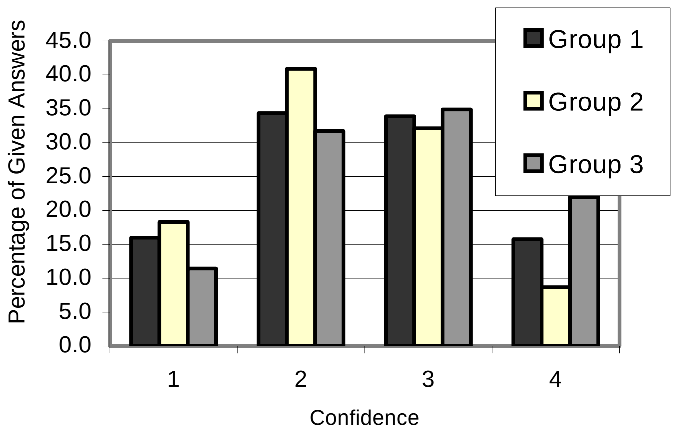

Figure 4: The confidence distribution of all the given answers by educational background.

The studied group included 56 female and 51 male students. There were 996 correct answers given, of which female students produced 45% and male students 55%. Altogether, there were 229 correct answers given with a confidence level of 4. Only 18% of these were given by female students, and 82% were given by male students.

Table 2: Students' confidence levels of the correct answers by gender.

Confidence	Female	Male	Female (%)	Male (%)
1	86	26	19.7	4.9
2	162	138	37.1	26.1
3	148	177	33.9	33.5
4	41	188	9.4	35.5

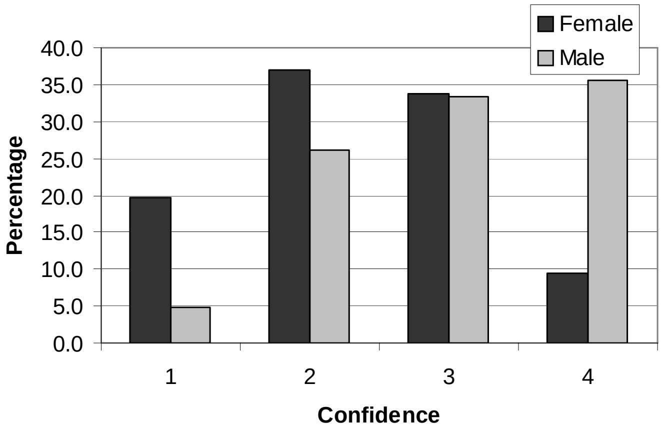

Figure 5: The confidence distribution of correct answers by gender.

In order to determine if the difference presented in Table 2 and Figure 5 was the result of previous education instead of gender, the authors examined the number of correct answers given by male and female students within the groups and the number of correct answers given with a confidence evaluation of 4. Table 3 shows the number and percentage of correct answers given by male and female students, showing also their educational background, as well as the number and percentage of correct answers given with a confidence level of 4.

When the distribution of correct answers (presented in Table 3) and the gender distribution of all students in the study presented in Table 1 are compared, it can be seen that the amount of correct answers given is quite well in line with the gender distribution inside the groups. Male students gave only slightly more correct answers than their female counterparts.

When the number of correct answers with a confidence evaluation of 4 is compared with the number of correct answers given, a clear difference between male and female students can be observed. Despite equivalent prior education, male students gave correct answers with a higher confidence level than the female students did. This confirms that the distribution, as seen in Table 2 and Figure 5, cannot be explained as an effect of previous education. These results also confirm those numerous studies that state that female students are less confident in their abilities than male students with the same educational background [3].

Furthermore, there is a clear difference of subject matter knowledge between groups 2 and 3 (see Table 3). Group 3 produced far more correct answers with a confidence level of 4 in proportion to the number of students that this group represented. Their background, with a broader education in physics, could clearly be seen. Group 1 produced correct answers with a confidence level of 4 well in proportion to the number of students this group represented.

By including the element of confidence, the authors expanded on the FCI and identified new insights and challenges in planning a course and teaching it. Two key questions are as follows:

- How can female students be encouraged to be more confident?
- How can students be taught to be more realistic when evaluating their knowledge and skills?

These are important goals when self-directed learning readiness and life-long learning are pursued. According to Gurian, both male and female students benefit from learning teams and group work, but female students like learning environments with social interaction and emotionality better than male students [21].

According to the authors' observations, taking the test clearly inspired and motivated students to investigate the impending physics course, even if the issues seemed very remote for students at that moment. The surveyed students wished that they could take the test again after the course.

The authors will proceed further with this research project by studying how the chosen teaching methods and arrangements influence learning and confidence levels.

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Table 3: Educational background for correct answers and correct answers with a confidence evaluation of 4.

	Group 1		Group 2		Group 3	
Students	M (33)	F (11)	M (8)	F (31)	M (10)	F (12)
Correct answers	296	61	78	235	162	127
% within group	82.9	17.1	24.9	75.1	56.1	43.9
Correct answers with a confidence evaluation of 4	90	2	24	19	74	16
% of correct answers (conf 4)	30.4	3.3	30.8	8.1	45.7	12.6

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