HOW DOES THE EXTENT OF STUDENT-ACTIVE LEARNING IN ENGINEERING PROGRAMMES INFLUENCE STUDENTS' PERCEIVED LEARNING OUTCOMES?

G. E. D. Øien [1]
Norwegian University of Science and Technology (NTNU)
Trondheim, Norway

I. Pettersen
Norwegian University of Science and Technology (NTNU)
Trondheim, Norway

N. R. Bodsberg
Norwegian University of Science and Technology (NTNU)
Trondheim, Norway

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ABSTRACT

Through the project "Technology Education of the Future" (FTS), NTNU has developed a framework for re-design of its study programmes in technology and engineering. One of the main findings is the need for a broader, more multidimensional view of graduate competence, showcasing the need to fully integrate training of several important non-technical professional skills in future programmes. To enable such integration, student-active pedagogical methods in combination with integrated learning principles are often seen as key tools. This paper quantitatively investigates to what extent study programmes' facilitation of active student participation actually makes a difference to perceived learning outcomes across a variety of competence areas. The research question under consideration is *"How does the extent of student-active learning in engineering programmes influence students' perceived learning outcomes?"* Using statistical analysis of data from a national student survey, correlation was investigated between students' perception of how well active student participation is facilitated by the teaching in their study programmes, and their self-evaluated learning outcomes in 10 different competence areas. Regression analysis was done based directly on individual student responses and on responses averaged over study programmes. The results show statistically significant positive correlation for most competence

[1] *Corresponding Author Geir Egil Dahle Øien, geir.oien@ntnu.no*

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areas. Students' perception of how well their programmes facilitate active student participation is found in good agreement with actual known programme characteristics. The results thus provide quantitative indication that improving facilitation of student-active learning in engineering programmes indeed improves learning outcomes for a broad set of future-relevant competence areas.

1 INTRODUCTION

1.1 Background and context

In August 2019, NTNU launched a project (FTS) for renewal of the university's programme portfolio within engineering and technology, with an ambition to *"promote a new generation of engineering and technology education which is updated in all areas according to international development and society's needs."* Initially FTS reviewed international trends and global best practices in technology and engineering education, as a starting point for SWOT analysis [1] and subsequent quality development in the FTS programme portfolio [2, 3]. This initial phase consisted of an outside-world analysis focusing on future global and national needs, major technology trends, and recent and expected developments in the higher education sector. Insights from this analysis were subsequently "triangulated" with input from faculty and students, advice from Nordic educational experts, and official university statistics, strategies and policies. Based on this foundation FTS subsequently created a set of overarching objectives for the future FTS programme portfolio consisting of a *vision*, a set of *principles,* and *competence profiles.* Finally FTS developed a *roadmap for implementation*, documented in [3, 4].

FTS identified some significant gaps between the status quo and international state-of-the-art in NTNU's engineering and technology portfolio at large, [1], e.g. widespread use of traditional lecture-based pedagogical practices, lack of integrated learning and coordination across courses, and too little emphasis on important '21st century' competences. It is however known that there are significant differences between programmes: Among the 5-year integrated technology master programmes, *Electronic System Design and Engineering (MTELSYS)* and *Industrial Design Engineering (MTDESIG)* in particular stand out positively wrt. student-active and experiential learning: Student-active learning and contextual learning are combined e.g. in an integrated set of courses in the first two MTELSYS years, focusing on conceive-design-implement projects, real-world problems, flipped classroom, campus spaces for student-active learning and peer-learning, and peer assessment and feedback. Peer assessment and team teaching are also prominent elements in MTDESIG, students being taught in dedicated studios and in-house workshops.

1.2 The national portal 'Studiebarometeret'

Among the most important data sources used in FTS' SWOT analysis [1] was *Studiebarometeret*, a national portal initiated by the Norwegian Ministry of Education and Research (KD) in 2014, and conducted by NOKUT (the Norwegian Agency for Quality Assurance in Education), an independent expert body under KD. Each

February, the portal presents results from an annual, extensive *student survey* sent to more than 70 000 2nd and 5th year students in around 1800 programmes nationwide [5]. Students are asked how they perceive many aspects of educational quality in their study programmes, for the purpose of strenghtening quality work in higher education and give education institutions, authorities, students and potential applicants useful information about educational quality and development over time.

Data from Studiebarometeret were used in several ways in FTS' SWOT analysis: For example, to analyze *overall student satisfaction, student workload, facilitation of active student participation, feedback from academic staff and fellow students, and perceived learning outcomes* for different types of programmes in the FTS portfolio.

1.3 Motivation for the present study

The focus of this paper is statistical analysis of data from *Studiebarometeret* to investigate *correlation* between *students' perceived degree of active student participation facilitated by their study programmes*, and their *self-evaluated learning outcome for 10 different competence areas.* The research question under consideration is: *"How does the extent of student-active learning in engineering programmes influence students' perceived learning outcomes?"* This is relevant because student-active pedagogical methods in combination with *integrated learning principles* are often promoted by educational developers and scholars of teaching and learning as key tools to achieve deeper learning and efficient integration of important professional skills into graduates' competence profiles (see e.g. [6]). *The CDIO Community*'s Standard 8, *Teaching and learning based on active and experiential learning methods*, states [7]: "*Active learning methods engage students directly in thinking and problem-solving activities. There is less emphasis on passive transmission of information, and more on engaging students manipulating, analyzing, evaluating and applying ideas.*"

At the same time, one sometimes sees a reluctance or scepticism among university faculty when it comes to making the move from traditional 'one-way' lecture-based pedagogy (often with an emphasis on theoretical aspects) to active and experiential methods as described above. Among the arguments heard against such a move are that it de-emphasizes the importance of theoretical knowledge and thus might threaten students' academic knowledge foundation; it is expensive and difficult to scale up to large classes; faculty are not trained in such methods and therefore do not know how to use them efficiently - thus the change might not work as intended.

The motivation for the investigation is to contribute to the understanding of *what the actual impact of student-active teaching methods is in the current FTS portfolio* - by seeing if it is possible to find a systematic coupling between students' self-assessment of their learning, and their perception of how well their programmes facilitate active student participation. The hypothesis is that a *positive* such coupling exists in a statistical sense, i.e. that *better facilitation of active student participation in study programmes on the average contributes to better learning among students*. If such a statistical coupling can be quantitatively demonstrated to be significant, it might serve as motivation for more programmes and courses to move quicker to a stronger emphasis on student-active learning, and for faculties and departments to invest more in competence development and infrastructure to enable the move.

2 METHODOLOGY

2.1 Student survey questions under consideration

In one section of Studiebarometeret's student survey, students are asked to assess their *Own learning outcome* so far, by answering the following question Q1 for the competence areas C1 – C10 in Table 1: *How satisfied are you with your own learning outcomes so far, concerning …*

Table 1: The 10 graduate competence areas investigated in Studiebarometeret.

C1	Experience with research and development work
C2	Discipline- or profession-specific skills
C3	Knowledge of scientific work methods and research
C4	Oral communication skills
C5	Critical thinking and reflection
C6	Cooperative skills
C7	Ability to work independently
C8	Written communication skills
C9	Innovative thinking
C10	Theoretical knowledge

In the survey's *Teaching* section students are asked how they agree with the following statement S1: *The teaching is organised so as to facilitate active student participation*. Answers are given on a 1 (Do not agree) to 5 (Completely agree) scale.

2.2 Statistical analysis – data and methodology

The data applied in the analysis in this paper are based on "NOKUT National Student Survey 2021, Subject Groups", financed by KD. The data are provided by NOKUT, and prepared and made available by the NSD (Norwegian Centre for Research Data). Neither NOKUT, KD nor NSD are responsible for the analyses/interpretation of the data presented here. Due to space limitations, the focus is only on data from NTNU's 17 5-year integrated Master of Science in Technology (*siv. ing.*) programmes [8]. Student responses are collected from the 2nd and 5th year of study, based on survey data from all years 2018 – 2021. The statistical significance of the relationship between learning outcomes and active student participation is tested by *regression analysis* [9]. Outcome is regressed on reported level of activity, year of survey, and overall satisfaction with study programme and year of study, for 4 underlying data distribution models:

A. Learning outcome is treated as a *cardinal variable* (underlying continuous distribution, discrete levels 1 – 5 uniformly spaced), and separate effects are estimated for different levels of active participation. Such effects are estimated with a reference category, in this case the lowest level of activity.

B. Both learning outcome and the measure of active student participation are modelled as *binary variables*, i.e., the original 5-point scales are quantized to binary scales. Values 4 and 5 are quantized to ‘1’, values 1, 2 and 3 to ‘0’.
C. The learning outcome responses are modelled as binary as in B, but separate effects are estimated for different levels of active participation.
D. Like B, but the learning outcome variable is in its original ordinal form, estimated by *ordered probit* [9].

3 RESULTS AND DISCUSSION

3.1 Results from data analysis

All regression models A-D above support a statistically significant relationship between students’ self-evaluated learning outcomes and their perception of study programmes’ facilitation of active student participation. This indicates that the trends and conclusions presented in this section are robust wrt. varying model assumptions.

Initially, results are presented from all 17 study programmes. In Fig. 1 the following competence areas, all important ‘21st Century Skills’, are considered: C6 *Cooperative skills*, C5 *Critical thinking and reflection*, C9 *Innovative thinking*, and C4 *Oral communication skills*. For each of these, individual programme data points are shown, each point averaged over all individual responses to statement S1 (x-coordinate) and answers to question Q1 (y-coordinate) from students within a study programme. *Best linear fits* to these points are also shown. Stronger correlation between x- and y-axis data corresponds to a *larger rate of change* (RoC) in the linear fits (positive RoC for positive correlation, negative for negative correlation). Note that the two programmes scoring highest on facilitation of active student participation are the MTELSYS and MTDESIG programmes (cf. Section 1.1).

Fig. 2 collects the best linear fits to the programme-averaged data points for *all* competence areas C1 – C10 in Table 1, plus a curve for the average over all the areas. For clarity, individual programme data points are excluded in this figure.

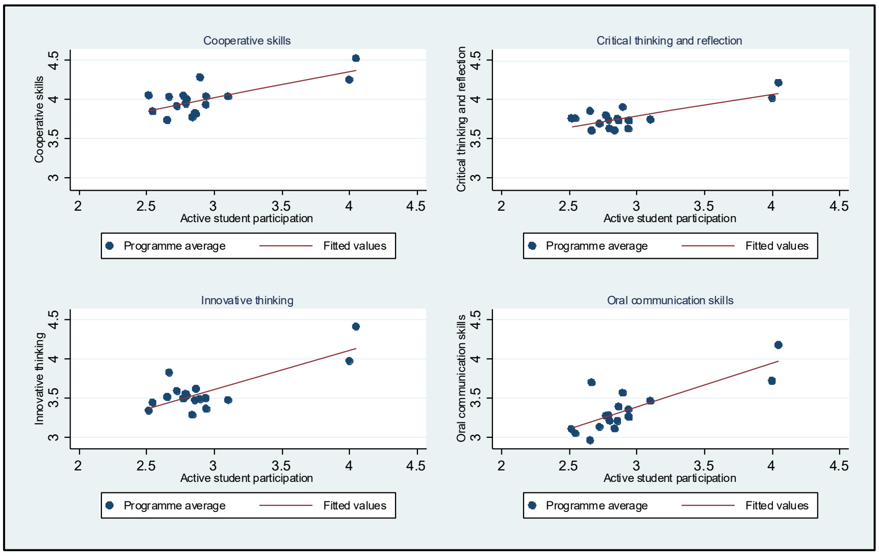

Figure 1: Individual programme data points and linear fits for Cooperative skills, Critical thinking and reflection, Innovative thinking, Oral communication skills. All programmes.

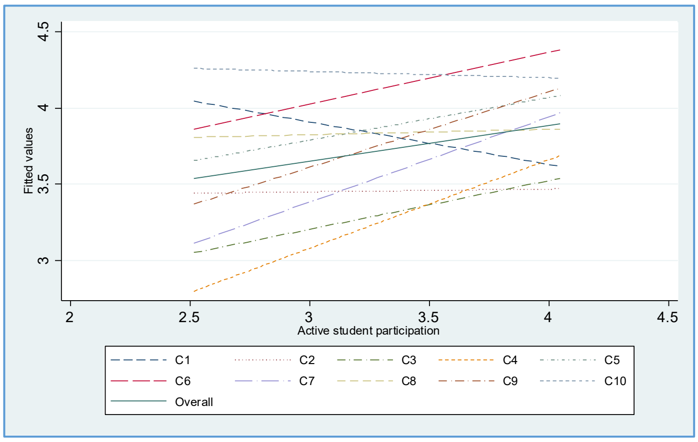

Figure 2 Best linear fits to study programme data for all competence areas. All programmes.

When including data from all 17 master programmes under study as in Fig. 1 and 2, the results show, for most competence areas, a statistically significant positive correlation between students' self-assessed learning outcome and their perception of how well their study programme facilitates active student participation. This is interpreted to indicate the importance of emphasizing student-active learning when designing study programmes with intended learning outcomes reflecting this range of graduate competences. However, the negative trend for competence area C10 Theoretical knowledge in Fig. 2 is potentially worrying: It seems to indicate that strengthening of competence areas C1 – C9 may come at the expense of less deep theoretical knowledge, thus supporting some of the faculty scepticism mentioned in Section 1.3. Upon investigation one however sees that the effect is isolated to only one of the 17 programmes: MTDESIG, whose data point is the lowermost of the two data points with highest x-axis score in Fig. 3 (the other one belongs to MTELSYS).

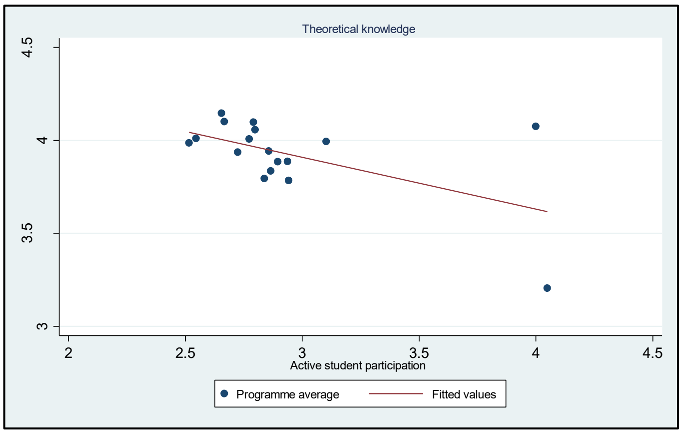

Figure 3 Individual programme data points with linear fit, Theoretical knowledge. All programmes.

Although its students are given a similar theoretical fundament during the first two years as those of the other programmes, MTDESIG as a whole is significantly more oriented towards design and aesthetic aspects, and less towards engineering identity, advanced technology development, and mathematical modeling, than the other programmes. One might therefore argue that a more fair and relevant analysis of 'typical' engineering programmes is actually achieved by excluding MTDESIG data. Fig. 4 present the same results as Fig. 1, but with MTDESIG data excluded.

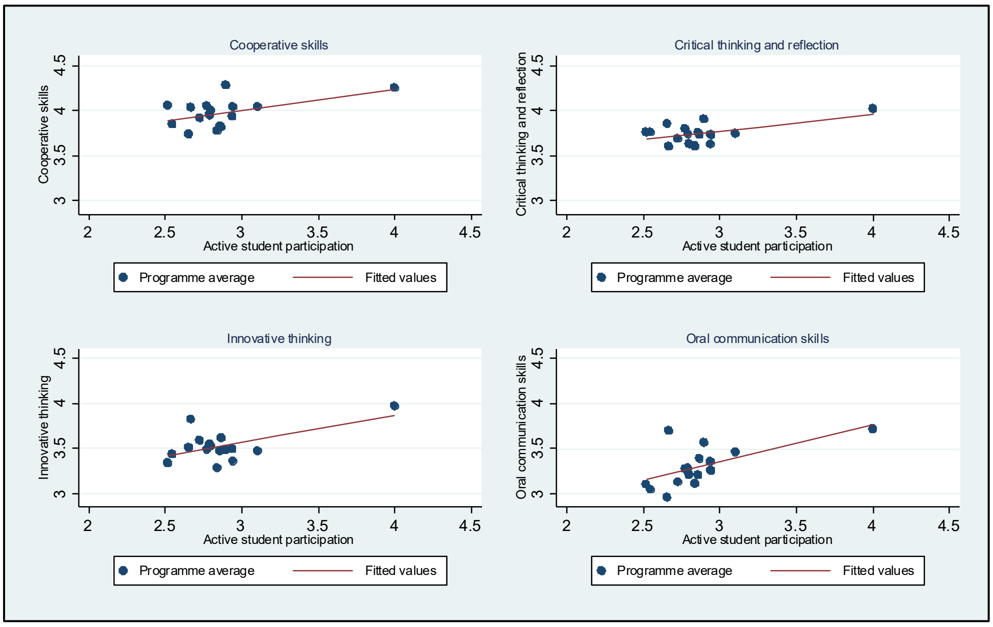

Figure 4: Individual programme data points and linear fits for Cooperative skills, Critical thinking and reflection, Innovative thinking, Oral communication skills. MTDESIG excluded.

When excluding MTDESIG one can no longer see a negative effect on competence area C10: Students' theoretical knowledge now appears not to be influenced at all by the level of active student participation (Fig. 5). The same holds for C1 *Experience with research and development work.* For C2 – C9 correlation is positive (Fig. 6).

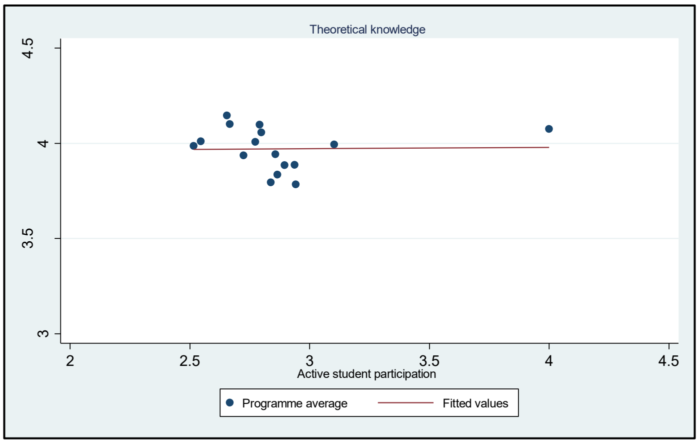

Figure 5 Individual programme data points with linear fit, Theoretical knowledge. MTDESIG excluded.

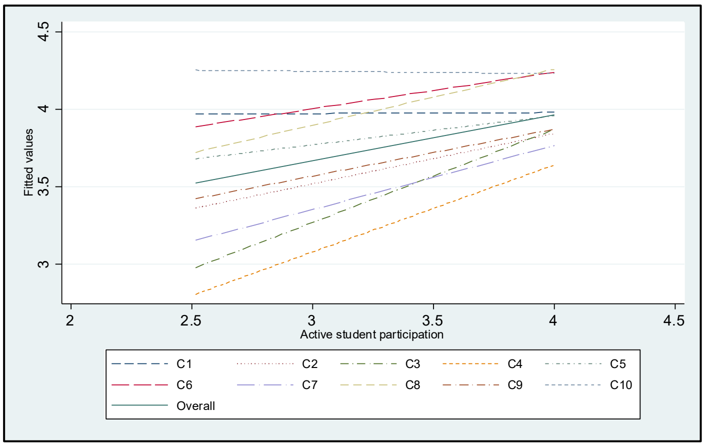

Figure 6 Best linear fits to study programme data for all competence areas. MTDESIG excluded.

3.2 Concluding remarks

One might ask: To what extent can one actually trust students' individual self-evaluation of their learning outcomes, and their perception of how well their study programmes facilitate student participation – i.e., how close are their judgments to actual fact? The answer to this question seems strongly linked to another important engineering competence: *Evaluative judgment* – '*the capability to make decisions about the quality of work of oneself and others*' [9]. The better universities are at developing this competence in students, the more one can probably trust their responses in studies such as this to be in line with actual fact. The authors of this paper acknowledge that as long as there is uncertainty or lack of knowledge about students' evaluative judgment ability, the results should be interpreted with caution, i.e., be treated as indications, not proof, of positive impact of student-active pedagogy in engineering programmes (also, statistical correlation is of course not synonymous with statistical dependency). Nonetheless, results seem to be well in line with recommendations based on state-of-the art research on learning [6].

As mentioned earlier, factual knowledge regarding the characteristics of the programmes under study may be used to gauge how students' perception agree with reality, when it comes to the programmes' facilitation of active student participation. The consistent scoring of the MTELSYS and MTDESIG programmes' teaching as the best in facilitating active student participation is in full agreement with known facts about those two programmes relative to the other 15 programmes under study (again, see Section 1.1). The fact that the other 15 programmes come across as more closely clustered around a narrower range on the x-axis is also in agreement with the fact that these programmes share many similarities in terms of overall structure, common basic and supporting courses, and pedagogical traditions and practice. Thus students' perception of their programmes' facilitation of active student participation seems to be in good agreement with known programme characteristics.

To gauge the reliability of students' *self-assessment of their learning outcomes*, one could e.g. analyse students' grades to check if the systematic differences between programmes are reflected there. However, this has not been done in this study. Also, results from such an analysis might not be so relevant or easy to interpret in practice, since the assessment methods used at present (with final written exams focusing on theoretical knowledge still the most common assessment method) are not necessarily well adapted to evaluation of all competence areas discussed here.

In conclusion, we believe that our results do provide a quantitative indication that

- More emphasis on student-active teaching methods in engineering programmes may indeed improve students' learning of a broad set of future-relevant engineering competences, and that
- it is possible to achieve this without weakening graduates' theoretical knowledge.

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