

# Inquiry-Based Learning in Engineering Education: A Norwegian Approach

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**Abstract**—Inquiry of research-based learning in the form of groupwork can easily end up being less than expected. It is because groupwork assessment is dealing with process and can be far trickier than assessing a team’s work dealing with product. This study aims to identify an assessment approach for effective inquiry-based learning in engineering education. For this purpose, four different perspectives were presented and discussed in combination with key constraints to implementing research-based learning. The perspectives include student reflection, collegial reflection, personal reflection, and literature. It was suggested that a combined method of continuous and qualitative assessment might be the most plausible.

**Keywords**—assessment, group assignment, group work, inquiry-based learning

## I. INTRODUCTION

In engineering education at university levels, it may be required to train the students on both:

- (1) Knowledge in engineering and technologies of relevance; and
- (2) Qualitative analysis and assessment of various technologies and systems for identifying the most suitable to the market need and the concrete circumstances.

Student achievements from the training are normally assessed through a final written exam of four hours as a norm in the Nordic countries. While this method may be sufficient to assess the learning outcome for the first requirement, it may be not suitable for the second due to the limited exam time.

When it comes to the task of assessing various available technological options to identify the most suitable one (considering different aspects, scenarios, and contexts), it normally requires apart from others substantially more time than that of an ordinary 4-hour written exam. As a complementary, inquiry-based, or research-based learning can be employed in addition to teaching and learning in ordinary class lectures.

The inquiry-based learning method is basically implemented in the form of group work, or group assignment in other words. For this purpose, especially for

the undergraduate courses I have been teaching at The Department of Energy and Process Engineering, Norwegian University of Science and Technology since 2010, the class of 35–45 students, most of which were international students mainly from Spain, Italy, Germany, and France, was divided into a number of smaller groups. Each of the groups normally consisted of 4–6 students, created via a random selection, and assigned a topic relevant to the course.

Alternatively, new topics of relevance proposed by students can also be accepted, in order to increase the flexibility and independency of the student in inquiry-based learning [1]. This can be seen in Table I, by examining the “Topic” for the last case “*Student Research*” of the inquiry evolution. Groupwork or inquiry-based learning organized this way can help students develop skills that are increasingly important in the professional world [2, 3].

TABLE I. INQUIRY EVOLUTION AND STUDENT INDEPENDENCE (ADAPTED FROM [1])

	Traditional Hands-on	Inquiry			
		Structured	Guided	Student Directed	Student Research
Topic	Teacher	Teacher	Teacher	Teacher	Teacher/Student
Question	Teacher	Teacher	Teacher	Teacher/Student	Student
Material	Teacher	Teacher	Teacher	Student	Student
Procedure/Design	Teacher	Teacher	Teacher/Student	Student	Student
Result/Analysis	Teacher	Teacher/Student	Student	Student	Student
Conclusion	Teacher	Student	Student	Student	Student

Unfortunately, research-based learning in the form of groupwork can easily end up being less than expected. It is because groupwork assessment is dealing with process and can be far trickier than assessing a team’s work dealing with product [4]. This was a practical problem of the courses I have been teaching for years in engineering education. Therefore, this study was performed to identify a suitable approach for inquiry-based learning and groupwork assessment. Effective evaluation of process requires thoughtful consideration of learning objectives and a combination of assessment approaches, which will be discussed in this report under the four lenses of reflection on university pedagogical perspectives:

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- (1) Student reflection.
- (2) Collegial reflection.
- (3) Personal experience; and
- (4) Literature.

The objective is to gain a better knowledge of how the implementation of the research-based learning in the form of groupwork can be improved, focusing on the assessment method.

## II. FOUR PERSPECTIVES

### A. Student Reflection

During the last ten years, student reflection on the groupwork of the courses was gathered via student reference groups. The student reference groups were established by selection of the volunteers and/or nominated students. Normally, each of the student reference groups was composed of 3–5 international and national representatives of both genders. The reference groups should have dialogue with other students throughout the semester. The reference groups may also choose to take other measures such as meetings or surveys before reference group meetings.

Every semester, two meetings of the student reference group were organized in person, with the presence of the course coordinator. In the meetings, among other, open discussion on the group assignment was a focus. Discussions and comments from the student reference groups were various and very constructive.

In the first instance, the students expressed their thought that group assignments were interesting. Since, the group assignment requires significant time and effort, a quantitative assessment of the assignment with grading and its weighing in the final grade was desirable by the students.

On the other hand, the students would like to have more detailed instructions and guidance on the group assignments. They also wished to have clearer requirements and assessment criteria.

### B. Collegial Reflection

There were two types of collegial reflection, which were created and had influenced on the improvement efforts for more effective inquiry-based learning through group assignment of the course. The first was in the form of consultation and discussion with both more- and less-experienced colleagues of my department and other departments of NTNU, including personal discussion and experience sharing in various workshop organized by my faculty.

The second type of collegial reflection was in the form of consultation with the administration of my department. It appears that groupwork assessment, both quantitative and qualitative, requires much resource especially concerning external censor. Indeed, it is not that easy to find an external censor (examiner) suitable for this task. Therefore, although the commitment of the department and higher management levels to undergraduate research via inquiry-based learning in the form of group assignment might be highly perceived, it was not clearly coordinated.

This is, however, a common issue in universities as reported in the literature [5].

### C. Personal Perspective

Overall, my own experiences and reflections on group assignment and assessment for the course are blended. In the first instance, it is positive to see that the students highly appreciated the group assignments, which were in line with the second objective of the courses, concerning the student training on qualitative analysis and assessment of various technologies and systems for identifying the most suitable to the market need and the concrete circumstances.

However, various problems and difficulties occurred during the groupwork performance. The measures for overcoming the problems and improving the performance were made upon the student reflections and practical issues, but perhaps not the best practices.

After a couple of years of running the course with ungraded groupwork, the first measure was taken to improve this course module upon the student reflection. The measure was to grade the groupwork. This grade then accounted for 20% of the final grade of the course. Improvements in the groupwork performance were observed.

However, two secondary problems were induced. First, some students tried asking for permission to join other groups of personal preference, instead of being grouped randomly. This was not considered as a good practice since the students were also supposed to learn how to work in a team with new people.

In addition, it resulted in extra and unwanted administration of the course. It is because someone in the receiver group needs to move to other groups to maintain even and reasonable sizes of all the groups. Second, due to practical limitations, the group grade was applied to all members of the same group. The more serious and industrious students who were working harder on the groupwork considered this unfair. This might have been one of the reasons of the first secondary problem.

On the other hand, it was difficult to bring the students into the learning process for the group assignment in a good time. Therefore, another measure has been employed for the course during the last couple of years to overcome this difficulty, which was in the form of supervised groupwork sessions. These sessions were designed to help the students with group assignments, step-by-step with particular tasks and more detailed instruction. The sessions were also designed to monitor the learning process and progress. This measure was highly appreciated by the students.

### D. Literature Perspective

A literature study shows that there are five assessment options for groupwork [4], which include:

- (1) Shared group grade.
- (2) Group average grade.
- (3) Individual grade – allocated task.
- (4) Individual grade – individual report; and
- (5) Individual Grade – Examination.

*Shared Group Grade* means that every group submits one final report, and all group members share the same grade, regardless of individual contributions.

*Group Average Grade* means that individual submissions (allocated tasks or individual reports) are assessed and scored individually. Each of the group members receives the average of these individual scores.

*Individual Grade – Allocated task* means that each student completes an allocated task that contributes to the final group product and gets the scores for that task.

*Individual Grade – Individual report* means that each student prepares and submits an individual report based on the groupwork on the task or project.

*Individual Grade – Examination* means exam questions specifically target the group projects and can only be answered or addressed by students who have been thoroughly involved in the project.

Each of the grading method for groupwork assessment has its own advantages and disadvantages. The advantages of *Shared Group Grade* include:

- (1) Encourages group work – groups sink or swim together.
- (2) Decreases likelihood of plagiarism (more likely with individual products from group work); and
- (3) Relatively straightforward method.

On the other hand, its disadvantages are:

- (1) Individual contributions are not necessarily reflected in the marks; and
- (2) Stronger students may be unfairly disadvantaged by weaker ones and vice versa.

*Group Average Grade* may provide motivation for students to focus on both individual and group work and thereby develop in both areas. However, it may also be perceived as unfair by students. Stronger students may be unfairly disadvantaged by weaker ones and vice versa.

*Individual Grade – Allocated task* is a relatively objective way of ensuring individual participation and may provide additional motivation to student potential to reward outstanding performance. However, it is difficult to find tasks that are exactly equal in size and complexity. In addition, it does not encourage the group process and

collaboration. Dependencies between tasks may slow progress of some.

*Individual Grade – Individual report* ensures individual effort and is perceived as fair by students. However, a precise way individual reports should differ often very unclear to students. In addition, the likelihood of unintentional plagiarism may be increased.

*Individual Grade – Examination* may increase motivation to learn from the group project including learning from the other members of the group. However, it also may diminish the importance of groupwork and result in additional work for staff in designing exam questions. In addition, it may not be effective since the students may be able to answer the questions by reading the group reports.

### III. DISCUSSION

Since groupwork assessment is essentially assessing a dynamic process, not a product, effective evaluation of process requires thoughtful consideration of learning objectives and a combination of assessment approaches. Groupwork is essentially designed to train students on developing various skills, such as communication skill, collaborative skill, writing skill, and skill of critical thinking. Therefore, quantitative assessment of the process of groupwork by grading is very demanding with a higher level of complexity.

Qualitative assessment of “*passed*” or “*approved*” may be more relevant. However, this approach may have negative impact on the student motivation of working in groups. The tendency of group members to exert less effort than they can or should be because of the reduced sense of accountability. Indeed, this kind of negative impact was observed in my course during the last couple of years and confirmed through the student reflection.

One way to overcome this problem is to apply the continuous assessment method, which may refer to assessing group processes via periodic process reports, self-evaluations, and peer evaluations as shown in Fig. 1.

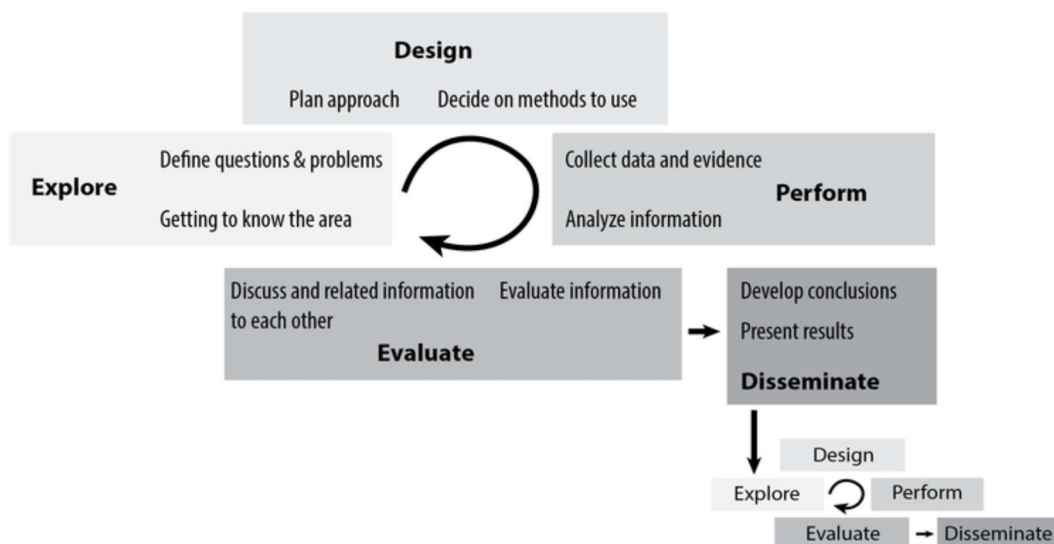


Figure 1. Inquiry-based learning process [1].

The process presented in Fig. 1 consists of five steps:

- (1) Explore.
- (2) Design.
- (3) Perform.
- (4) Evaluation.
- (5) Disseminate.

The first step of *Explore* starts with literature search and reading, getting students to know the area. The second step is *Design*, where students will define study questions and problems. During this step, students will train on defining the objective, scope, and methodology (how to achieve the objective).

Next is the step of *Perform*, during which students will develop the main contents and a work plan. For this purpose, students will collect relevant data, information, and evidence, which are then analyzed and interpreted. The fourth step is *Evaluate*, of which discussion and comparison (with related information or research) is a focus.

The four first steps are together composed of a looping process, which will be repeated after the fifth step of *Disseminate*.

This method has been adopted for my course during the last couple of years. The step of *Disseminate* was conducted in the form of *Flipped Classroom*, which is defined as “*Teachers shift direct learning out of the large group learning space and move it into the individual learning space with the help of one of several technologies*” [6]. It is because flipped classroom helps promoting student engagement and preparation in pre-class activities [7].

Flipped classroom was designed for my course to monitor the process of the inquiry-based learning process and to address possible questions from students. It appears to be highly appreciated by students, which is in good agreement with the literature [8].

The adaptation of this method showed some improvements and can serve as the first lens under discussion. It would be even better to combine with a quantitative assessment of the final groupwork report. The Shared Group Grade from this quantitative assessment should be then weighted by 20–30% in the final grade in order to increase the sense of accountability for the groupwork.

On the other hand, there exist challenges and barriers to implementing research-based learning at undergraduate levels [5]. The key perceived constraints included institutional policies, academic perceptions of the challenges and barriers, as well as questions of time, funding, and resources.

Different attitudes and lack of skills of how to implement research-based learning led to different practices and opportunities for further development.

The commitment of a university to research-based learning at the highest policy level is considered important but needs to be supported by facilitative structures.

Other literature suggests that implementation of research-based learning is seen not as integral to academic practice but as a “*burdensome*” and “*troubling*” extra, that

adds to the commonly assumed high academic workload [9].

By taking all the aforementioned aspects and discussions into consideration, it seems that a combination of the continuous assessment method with a qualitative assessment of the final groupwork report would be optimal for group assessment.

#### IV. CONCLUSION

Groupwork assessment is essentially assessing a dynamic process, not a product. Effective evaluation of process requires thoughtful consideration of learning objectives and a combination of assessment approaches. Quantitative assessment of the process of groupwork by grading is very demanding with a higher level of complexity.

Qualitative assessment of “*passed*” or “*approved*” may be more relevant but have negative impact on the student motivation of working in groups.

Based on the different possibilities and constraints presented it seems that a combined method of continuous and qualitative assessment may be the most plausible and promising approach to implementing the groupwork assignment and assessment for an effective research-based learning.

#### CONFLICT OF INTEREST

The author declares no conflict of interest.

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