An Approach of Formative Assessment for Capstone Design Project Course

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Abstract

This paper presents an approach to conduct formative assessment of Capstone Design course. Formative assessment is a self-reflective process that intends to promote a learner to obtain an adequate level of skill of some subject. Formative assessment works as a means of adapting learners' needs and their attainment, and stands opposed to summative assessment which provides an indicator of progress at the end of particular learning course.

For almost ten years, we have been evaluating undergraduate students' expected learning outcomes, and, as a means of measurement, the author's program makes use of Capstone Design course to assess students' learning outcomes which include abilities of conducting experiments and data analysis, problem solving, system/component design, teamwork, and efficient communication. Therefore, it is imperative to adopt the formative assessment to improve overall program outcomes in Capstone Design course.

In this paper, we describe our experiences in Capstone Design course with formative assessment methodology to improve our program's outcomes by boosting students' learning outcomes of Capstone Design course. To improve students' learning outcome, we have designed Capstone Design course by applying a number of proven techniques with respect to the formative assessment, by introducing a formative assessment approach that encourages students to meet all criteria of program outcomes. Fundamentally, we have designed a formative feedback structure where students recognize course outcomes explicitly and prepare for improving their skill in terms of course outcomes by self-motivated problem-solving and peer learning. In addition, student assessment results will be presented for discussion, and we will propose considerable extensions possible.

Introduction

Since its first introduction of Engineering Accreditation into engineering education programs over almost 10 years, Information and Communication Engineering (ICE) program at Dongguk University has been evaluated its engineering education quality via various evaluation methodologies and conducted a lot of effort to improve program quality. To this end, ICE programs at Dongguk University have been measuring undergraduate students' expected learning outcomes using several performance indicators and estimating programs' overall quality and effectiveness. From this context, program's outcomes can be defined as beneficial changes for program participants that include changes in skills, knowledge, behavior, attitude, status, or life condition. Students' expected learning-outcome evaluation is also defined as an action of assessment for a program's educational impacts and benefits over students participated in each program [1,2]. The assessed results of students' learning outcome can be used as a program planning and program advocacy tool. We call this usage of these assessment activity and result evaluation for the program improvement as CQI (continuous quality improvement) structure.

Capstone Design course is known to be a good assessment tool for evaluating program outcomes [3]. Capstone Design course requires abilities for engineering students individually or collaboratively to apply classroom knowledge and skills to realistic design problem. Such abilities include capabilities of "problem definition", "gathering and analyzing relevant data", "generating solution alternatives", "choosing the optimum solution given explicit and implicit constraints", and "effectively reporting results". Those abilities are also mandatory abilities that engineering students must demonstrate for the purpose of accreditation. Therefore, given well-designed scoring rublics and methodologies, the performance in Capstone Design course can provide a good measure for evaluating engineering program outcomes, as the abilities required in Capstone Design course are also students' mandatory abilities for the engineering accreditation program. For such reason, many accreditation engineering programs including ICE program at Dongguk University make use of Capstone Design course to assess students' learning outcomes which include abilities of conducting experiments and data analysis, problem solving, system/component design, teamwork, and efficient communication.

Educational experts recommend the use of formative assessment in addition to summative assessment to get more achievement of educational objectives. Formative assessment is a self-reflective process that intends to promote a learner to obtain an adequate level of skill of some subject [4,5]. Formative assessment works as a means of adapting learners' needs and their attainment, and stands opposed to summative assessment which provides an indicator of progress at the end of particular learning course [6,7]. The purpose of formative assessment is providing direct feedback about the learning and teaching process in order to give beneficial effects for both students and teachers, and hence enhance the extent to which learning outcomes are achieved.

Considering programs learning outcomes are closely related to Capstone Design course outcomes, there should be no doubt to adopting formative assessment in Capstone Design course. Self-reflective nature of formative assessment would make students capture outcomes explicitly and encourage themselves to achieve those outcomes. Introducing formative assessment is able to provide opportunities that student improve their educational skills related to program outcomes, though summative assessment only provide measurements how student achieve program outcomes. Therefore, it is imperative to adopt the formative assessment into Capstone Design course.

In this paper, we introduce our approach of adopting formative assessment in Capstone Design course in ICE at Dongguk University. To design Capstone Design course, we first examined ICE program outcomes and Capstone Design course outcomes and figured out how ICE program outcomes can be achieved via Capstone Design course. We found out almost half of program outcomes can be achieved through Capstone Design course and well formed Capstone Design course can enhance student performance in terms of program outcome. Then we designed the methodologies of formative assessment and adopted that into Capstone Design course. The methodologies we used are those who are used in class are not new. Those methodologies are used widely in formative assessment. Rather than focusing on developing new methodologies, we gave more attention on when to use such methodologies to improve course outcome. To this end, we modify Spiral model from Software Engineering process. The evaluation results show our approach is effective in terms of achieving program outcomes.

This paper is organized as follows. Next section describes ICE program learning outcomes and Capstone Design course outcomes and compare them how they are related each other. Then, we introduce our strategy to employ formative assessment to improve course outcomes focusing on enhancing ICE program outcomes. The evaluation results will be provided in the following section, and finally we discuss the effects and further considerations of adopting formative assessment at the conclusion section.

Program Outcomes and Capstone **Design Course**

Most of engineering programs which are under engineering accreditation require their graduate to have various abilities described in the criteria from KEC 2000 or KEC 2005 [8]. According to Accreditation Board for Engineering Education of Korea (ABEEK), all the engineering programs under engineering accreditation must have an appropriate assessment process that produces documented results that demonstrate that students have satisfied each and every criteria associated with program outcomes based on KEC 2000/2005. In other word, it is expected that every students must achieve every single ability that is listed as a program learning outcome.

Most of these abilities can be reinforced from design experiences of Capstone Design course. Although not explicitly required, a capstone design involves team-based experiences, calls for the understanding ethical and professional responsibilities and effective communication skills, and employ consideration of realistic economic, operational, technical, and schedule constraints. Therefore, most abilities enhanced through capstone design experience are closely related with program outcomes listed in KEC 2000/2005, and hence program learning outcome is without doubt achieved through capstone design experience. In addition, it is certain that the evaluation for some of program's learning outcomes can be conducted through capstone design course at the same time.

For our convenience and effective educational effects, we selected some of mandatory program outcomes in order to focus on enhancing student achievement through capstone design experience. The learning outcomes guide course design covering teaching, learning and assessment activities. So, selecting learning outcomes or prioritizing outcomes are important since they made heavy effects on any decision related to course design.

The selection criteria are based on capstone design course objectives Table 1 and our study considering the extent of effectiveness for student outcome achievement.

Table 1: capstone design course objectives in ICE at Dongguk University.

	Capstone Design Course Objectives
1	An ability to apply knowledge from earlier course work to solve engineering problem
2	An ability to formulate engineering problems and design a process.
3	An ability to use the techniques, skills, and tools to solve self-selected engineering problem
4	An ability to function on multi-disciplinary team and communicate effectively.

The abilities we selected are listed in Table 2. Outcomes in Table 2 are outcomes that we focus using formative assessment methodology to improve student achievement. Compared to objectives in Table 1, selected outcomes in Table 2 are more closely related than other mandatory program learning outcomes listed in KEC2000/2005.

Using Formative Assessment?

Based on Black and William's definition [9,10], formative assessment is an assessment methodology that encompass teacher observation, classroom discussion, and analysis of student work and their achievement including homework and tests. Such assessment methodology is called formative as the information is used to adapt teaching and learning to meet student needs. When teachers know how students are progressing and where they are having trouble, teachers can use this information to make necessary instructional adjustments, such as reteaching, trying alternative instructional approaches, or offering more opportunities for practice. These activities can lead to improve student success.

Table 2: abilities we focus on for formative assessment

learning outcomes	Outcomes Description
Outcome 2	an ability to design and conduct experiments as well as to analyze and interpret data.
Outcome 3	an ability to design a system, component, or process to meet desired needs within realistic constraints.
Outcome 4	an ability to identify, formulate and solve engineering problem
Outcome 6	an ability to function on multi-disciplinary teams.
Outcome 7	an ability to communicate effectively.
Outcome 11	an understanding of professional and ethical responsibility.

In terms of Capstone Design course work assessment, we have opted for formative assessment rather than summative assessment (opposed to formative assessment) for several reasons. The first reason is that capstone design process is an iterative process that requires creativity and reflection. Process in capstone design involves considering options and making sensible tradeoffs. The second reason is that the traditional exam of summative form has intrinsic limitations to guarantee students achievement based on program outcome criteria. Traditional assessment (called summative assessment here) is appropriate as the assessment measures students' functional knowledge.

However, we are searching a method for a method that could actually guarantee all the students satisfy given criteria. Therefore, we have no alternative but adopting formative assessment methodology. The third reason is based on the characteristic of capstone design course. Students work in capstone design course is carried out via problem solving approach for open question. Therefore summative assessment is not appropriate as such assessment requires fixed set of answers.

The five elements in formative assessment are summarized by Crooks [11] and described as follows.

1) Make learning objectives understood and shared by both teachers and students.
2) Help student to understand and recognize the desired criteria.
3) Involve students in self-assessment.
4) Provide feedback which helps student to solve open questions.
5) Build confidence that student can improve their work.

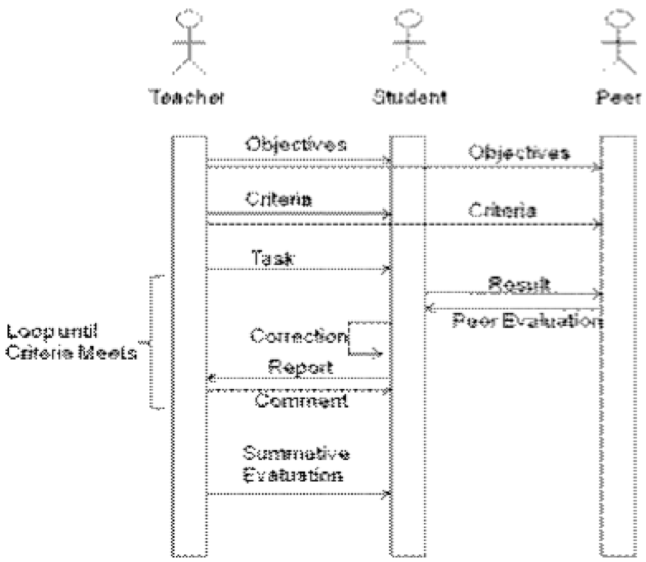
Based on the above key elements, we identified the most important aspect in designing coursework based on formative assessment approach is to decide how to build the feedback structure. Therefore, we designed a feedback structure with respect to the five elements summarized above. Our feedback structure in ICE program's Capstone Design course is illustrated in Figure 1.

Our feedback structure include the student's peer commenting on and grading the student's work. The teacher's role may be to initiate the feedback loop by setting task or problem as well as providing evaluation criteria where the criteria is used for students' self-evaluation along with peer evaluation. Peer evaluation is carried out in cooperative way rather than competive way, such that it can encourage confidence on student work. Teacher then provide students enough time to correct their work and then offer suggestions on the corrected works. These feedback structure repeats until students work can satisfy criteria.

Course Design for Formative Assessment

In the previous sections, we identify course outcomes to be assessed and assessment structure focusing on feedback structure. As a next step, we designed Capstone Design course organization based on formative assessment way. To this end, we have made decisions on how the course organized and which means we will use, and defined three basic principles to be respected toward our decisions as follows.

Figure 1. A Feedback Structure for Formative Assessment



1) Allow students sufficient time to build their knowledge structure as much as possible

- this is the most time-consuming principles. However self knowledge acquirement helps students develop their connections between their knowledge and problem solving domain. So this is inevitable principle even though the most time consuming.

2) Facilitate active and peer learning

- Active learning is essential for acquiring functional knowledge necessary to satisfy objectives maintaining students' confidence. Peer learning offers students broaden views of self assessment and extension of their learning experience.

3) Use feedback structure

- feedback is one of key element in formative assessment. We identified why we need a formative approach in previous section, and described our design on feedback structure.

Capstone Design course in ICE program at Dongguk University has 6 basic tasks: Problem Identification, Scope Definition, Domain Analysis, Logical Design, Physical Design and Feasibility Analysis, Implementation, and Testing. Each task is evaluated separately using formative assessment methodology and each assessment encapsulates a feedback loop including self-assessment and peer-review. Table 3. shows our capstone design course structure and schedule for each task. Cells marked with dark color shows a feedback loop described from the previous section.

Table 3. Capstone Design Course Organization

Tasks	Problem Statement	Scope Definition	Domain Analysis	Logical Design	Physical Design and Feasibility Analysis	Implementa-tion and Testing
Week 1						
Week 2						
Week 3						
Week 4						
Week 5						
Week 6						
Week 7						
Week 8						
Week 9						
Week 10						
Week 11						
Week 12						
Week 13						
Week 14						
Week 15						
Week 16	Summative Assessment for Final Report and Demonstration					

Each task has its own independent objectives and criteria, and Table 4. shows objectives and evaluating criteria for each independent task. These objectives and evaluation criteria are selected to reflect course objectives and program outcomes. They are noticed to students right before the phase of each task begins, and students conduct self-assessment and peer-evaluation based on the evaluation criteria. Teacher also provides feedback for students work on each task.

Table 4. Objectives and evaluation criteria based on task type

task	Task Objectives	Evaluation Criteria
Problem Statement	- Topic selection - Problem definition - Project object identification - Deliverable and opportunity definition	- Adequateness of problem range - Adequateness of object identification - Adequateness of deliverable. - Correctness of opportunity
Scope Definition	- Constraints identification - Requirement analysis	- Consideration of economical, technical, operational and schedule constraints - Correct requirements documents - Requirements confliction - Prioritizing system requirements
Domain Analysis	- Acquiring domain knowledge - Acquiring technical standards and technology availability - Functional requirements identification	- Knowledge of technical standards for target domain - Analysis of available technologies - Domain level feasibility study in terms of technical skills. - Number of references used - The degree of relations between references used and the target domain. - Range of functional requirements
Logical Design	- Fomulate problem space. - Selecting core algorithm or general solution - Build general architecture for application. - Logical module decomposition - Role assignment for the decomposed module	- Correctness of problem fomular - Correctness of architecture design. - Correctness of design tool usage. - Correctness of module decomposition - Equal job distribution - Explicit and clear role assignment
Physical Design and Feasibility Analysis	- Analysis of alternative solutions for modules - Feasibility analysis for each alternatives based on technical, operational, economical, and schedule aspects.	- The number of alternative solutions. - Correctness of feasibility analysis. - Range of consideration in feasibility analysis
Implementation and Testing	The degree of satisfaction for functional requirements	The degree of satisfying functional requirements.

Evaluation Result

Capstone Design course is mandatory for ICE program students to graduate. So each year almost 100 students take Capstone design course. For the evaluating purpose, we separate classes into two groups: classes using formative approach and classes using summative approach. From the characteristics of capstone design course, - feedback is required element - we did not remove feedback from summative classes. Therefore, we take alternative course design – smaller number of explicit tasks (3, project proposal, architecture design, implementation and testing) and no peer review activity -. The smaller size of assessment tasks and limited review activity makes alternative course drives alternative course more summative way. Therefore, we become to be able to compare the performance of both classes.

For our experiment, we use classes that are open on 2007 Fall semester and 2008 Spring semester as summative class sample, and classes held on 2008 Spring semester and 2008 Fall semester are used as formative class sample, where all of those classes are managed and instructed by same teacher. Since summative classes are open earlier than formative classes, we re-evaluated student performance on December 2008 for those classes and the evaluation results are described in Figure 2. Evaluation rublics are defined based on Table 2 program outcomes. As Figure 2. shows, performance from formative classes improves than summative classes. Particularly for outcomes 3 (system design ability) and 4(problem solving), we can notice significant improvement. However, summative class still shows qualification of program outcome criteria. The reason would be that ICE program provide a number of design classes before Capstone Design course, so student are already educated in terms of program outcomes and well aware of how to achieve learning outcome criteria. The scores for each outcomes are normalized to 5 point scale.

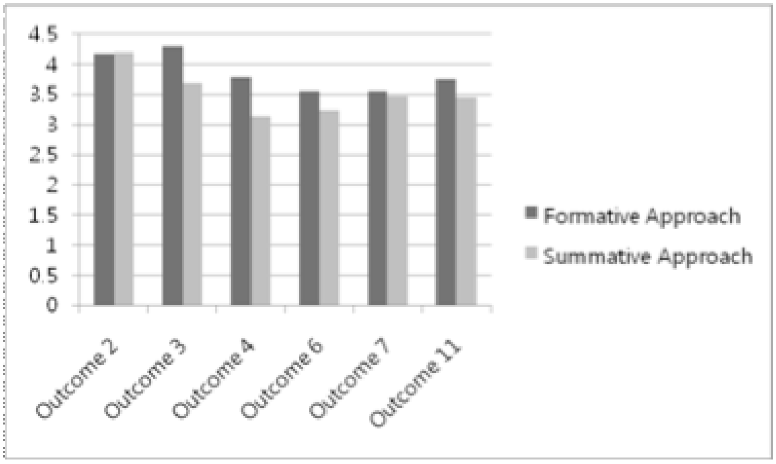
Conclusion

In this paper, we have describes our experience of running Capstone Design course using formative assessment approach. To this end, we first design a novel feedback structure that embrace formative principles. Then, we build the course organization and define tasks that will be assessed through formative approach. Along with task definition, we identified task objectives and criteria that will be used for assessments. Whenever every task starts, we follow the feedback structure involving self-assessment, peer-review, and teach commenting.

We also justify our formative assessment approach. We have compared Capstone design course objectives and ICE program outcomes, in order to show Capstone design course is efficient tool for achieving program learning outcome. Identifying key elements for formative assessment from literature justify our work on capstone design course.

However, there problems are also notified. The most notable problem is the fact that students suffer from the burden to building output works for every 3 or 4 week. Communication overhead and delay is another problem since as class size gets bigger the size of communication grows exponential. So finding adequate size of class students and figuring out proper amount of course works is vital future works in order to adopt formative assessment methodologies in capstone design course.

Figure 2. Comparison of performance between summative and formative classes.



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