Concept Group Exercises for Continuous Improvement of Students Learning Abilities

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Abstract

Continuous learning improvement is highly desired to develop thorough understanding of the subject matter, which can be achieved by practicing active/collaborative learning strategies. For the undergraduate Fluid Mechanics class, in addition to practicing active learning, concept-based group exercises were developed and routinely conducted in a class after every four lectures to examine students’ understanding of the subject matter. For instance, after lecturing on momentum balance and Navier-Stokes equations, student groups were asked a specific flow problem that would demonstrate the concepts of setting up general momentum balance and Navier-Stokes equations with appropriate selection of velocity vectors and finding their solution by using discretized algebraic equivalent equations and computational fluid dynamics software. These concept exercises were categorized as “basic, moderate and advanced” based on the complexities involved. Moderate and advanced group exercises were designed to develop critical thinking abilities. The posttest scores significantly improved after the administration of concept group exercises. The answers obtained from the groups were discussed in the class and those groups with incorrect answers were helped by the instructor and other student groups. The successful outcome of this effort was that the entire class reasonably attained the same level of understanding of the subject matter.

1. Introduction

Continuous learning improvement is highly desired to develop thorough understanding of the subject matter, which can be achieved by active/collaborative learning strategies. Collaborative learning concepts involving the grouping and pairing of students for the purpose of achieving an academic goal has been researched and promoted throughout the education literature. In collaborative learning method, students at various performance levels work together in small groups toward a common issue. Supporters of collaborative learning claim that the active exchange of ideas within small groups generates increased levels of interest among the participants and promotes critical thinking abilities. It is also known that the cooperative teams achieve higher levels of thought and retain information longer than students who work individually. Collaborative learning gives students an opportunity to engage in discussion, identify knowledge gaps and seek new knowledge, and thus become critical thinkers.

As today’s global competitive economy relies on a complex industrial network that often demands engineering graduates with exceptional problem solving skills, teamwork, communication skills, and critical thinking ability, it becomes imperative to look for innovative instruction approaches to prepare students. Such skills and abilities can be achieved by inducting a coupled approach involving collaborative and problem based learning strategies in curricula. Both cognitive and generic skills will be realized by practicing collaborative learning and problem based learning approaches that involve several self-directing learning demonstrations in transitioning from problem analysis to reporting-reflection to integration and evaluation. Collaborative learning facilitates concept learning of the subject matter and can therefore aid in
problem solving abilities among the students. This paper emphasizes concept learning through the collaborative learning approach.

Concept learning is the key to the continuous improvement of students’ learning abilities; however, the author believes that its effectiveness greatly varies with whether it is induced on an individual or group basis. Many researchers describe concept learning as a process of refinement, organization/reorganization and enrichment of knowledge.\(^4,5\) In every lecture, as students are not always informed about the principles of phenomena, they need to often reconstruct phenomena with concepts and theories they have already learned and fragment knowledge that will translate into a more organized and coherent concept structure.\(^6,7\) Concept learning is viewed as construction and transformation of individual knowledge that is sometimes reflected by memory or mental models. Many times if a student starts with some preconceptions of the subject matter that are somewhat relevant, the possibility of developing misconceptions is very high. Conceptual learning can be just another transformation that students develop from the knowledge embedded in theoretical frameworks.\(^8\) However, if we take a more cautious approach in developing such transformations among the students by directing their collaborative participation in classroom activities, more productive outcomes may be achieved. In general, it is believed that participation in collaborative learning activities gives students more opportunities in developing conceptual learning through social interactions among peers. This we can refer to as concept group learning activity.

In a group environment, conflicts and controversies are resolved through proper explanation, justification; reflection and search for new knowledge.\(^8\) Student groups often come up with mutual support or solution via elaborative help that stimulates reorganization of thoughts and identification of knowledge gaps thereby generating solution seeking ability among the student group members. These circumstances also help students developing elaborate conceptual understanding by making use of new analogies, revisiting and reformulating their knowledge, which becomes more coherent among the group members.\(^9,11\) In a group environment, student co-construct\(^12\) an understanding of the subject matter by exploratory and cumulative talks, which can yield more productive and desired results. Such opportunities of concept learning are missing in the individual learning approach. Thus, collaborative learning activities will be more useful in concept learning.

This paper reports the effectiveness of concept group exercises on the continuous improvement of students learning abilities, which was investigated in an undergraduate Fluid Mechanics class. These exercises were developed and routinely conducted in a class among student groups after every four lectures to examine their understanding of the subject matter. These group exercises were developed to facilitate conceptual understanding of the subject matter through collaborative learning approach. Such a concept group exercise might be considered as a group test and should not be confused with the database on conceptual questions available in the resource such as AIChE Concept Warehouse, which is a great resource for creating a community of learning focused on conceptual understanding.
2. Purpose of Study

This study was conducted with two objectives: 1) examine effectiveness of individual learning versus collaborative learning and 2) investigate the effectiveness of concept group tests on students learning abilities.

3. Instrument and Methodology

Subjects: The population of this study consisted of undergraduate students in Fluid Mechanics course, CBE218, in Chemical and Biological Engineering at South Dakota School of Mines & Technology, Rapid City, South Dakota. The class of 37 was a mix of 11 sophomores, 20 juniors, and 6 seniors. The student population was divided into 8 groups of 4 students and one group of 5 students. Student groups were formed by self-selection and the instructor did not influence group forming decision. Generally groups smaller than 3 students lack diversity and collective decision making ability, whereas, larger groups pose difficulty in ensuring participation of all student members. Therefore, all groups except one consisted of four student members.

Parameters and variables: Method of instruction was used as a constant parameter whereas concept group exercise and posttest were termed as independent and dependent variables, respectively. Exercises were a combination of ‘drill-and-practice’ and critical thinking skills.

Treatment: The treatment comprised of three parts: 1) lecture, 2) concept group exercise, and 3) individual test. After every four 45 min lectures, the fifth lecture was delivered for first 15 min and a concept group exercise was conducted for the remaining 30 min. Collaborative learning, concept group exercise and its purpose was clearly explained to the students and they were given 3 tasks of 10 min each. Individual learning exercise was administered for 30 min before and after administration of a concept group exercise. This is to analyze the effectiveness of concept group exercise on individual learning. Individual exercise prior administrating the concept group exercise was referred as pretest whereas test after administrating the group exercise was considered as posttest. Specific examples of group and individual learning exercises are illustrated later.

Instrument: The pretest and posttest were developed by the author based on the guidelines provided in Blooms taxonomy\textsuperscript{13}. Knowledge, comprehension and application were categorized as drill-and-practice, whereas synthesis, analysis and evaluation were classified as critical thinking skills.

4. Research Design

The research problem was designed to investigate, if there is a significant difference between students’ individual learning through individual test and students learning collaboratively through concept group exercises. The design also included the effectiveness of concept group exercises on improving individual student learning ability. The pretest was helpful in assessing students’ knowledge and concept understanding on an individual basis. The posttest was administered to measure the treatment effects.
5. Representative Examples of Individual/Group Concept Exercise Questions and Results

*Individual concept test (pretest) question prior inducting concept group exercise*

**Example 1**

A liquid flows down an inclined plane surface in a steady fully developed laminar film of thickness ‘h’ as shown in Figure 1. Analyze this flow system by assuming that there is no ‘z’ velocity component, no variation in fluid property in ‘z’ direction and pressure and gravity terms are non-zero and answer the following.

![Figure 1: Fully developed laminar flow of a fluid over an inclined surface.](image)

a) Which co-ordinate system will you take into account? b) Is there a need to write equations for all velocity components? If not, then which ones you consider as non-zero? c) What typical assumptions one can make to analyze the flow system using Navier-Stokes equations? d) After you determine non-zero velocity components, write simplified form of the Navier Stokes equations. e) Suggest a workable form of equation that can be used to find the average velocity or volumetric flow rate.

**Summary of student responses**

As the test was *open book and open notes* many students answered questions (a) and (c) accurately. Students struggled to answer (b) and (d), which required understanding of the equations and meaning of different terms in the equations as well as it involved decision making about non-zero terms. As students faced difficulty in answering (b) and (d), coming up with the workable form of equation (asked in question (e)) was difficult. Questions (b), (d) and (e) were somewhat related to critical thinking involving synthesis, analysis and evaluation. The pretest individual test scores are shown in Figure 2, which indicated a maximum point score of 37.6 and a minimum score of 9.2 with the class average of 29.9/50.

![Figure 2: Pretest scores of individual students.](image)

There were multiple reasons that the above concept exercise was administered, which included- i) the instructor felt that there was enough traditional lecturing on principles, concepts and applications to different flow situations, ii) the instructor believed that the students should do well in the examination as they actively participated during classroom lecturing and iii) the students in future should be able to solve problems on these concepts and extract quantitative information. Based on the student responses, the author realized that there was a need to develop concept exercises providing understanding at basic, moderate and advanced levels. The author graded the test and took it back to the class and asked if another opportunity was given to them would they...
consider taking the same examination on a group basis and 99% class agreed that this could have been done on a group basis and not on individual basis. Students’ rationale argument was that they knew the concepts/equations but they wanted to confirm with their peers. This situation made a very strong case for the development of concept group exercises. It was believed that such concept group exercises would likely refine knowledge, develop reorganization of thoughts, identify gaps, enrich knowledge and develop reflecting ability through social interactions.

As engineering students have to eventually perform problem solving exercise, the author planned next activity involving the examination about extracting the quantitative information. Below describes the example.

**Example 2**
Solve for \(V_x\) as a function of \(t\) (time) and ‘\(y\)’ using the following equation in which at \(t=0\), the velocity is zero everywhere, and for \(t \geq 0\), \(V_x\) at \(y=0\) is 2 ft/s, and the fluid is water (\(\nu = 10^{-5}\) ft\(^2\)/s). Choose time interval of 2 sec and distance step (delta \(y\)) as 0.05 ft for the calculations.

\[
\left( \frac{\partial V_x}{\partial t} \right) = \nu \left( \frac{\partial^2 V_x}{\partial y^2} \right)
\]

Use discretized algebraic equivalent of the above equation and by creating a x-y grid calculate velocity at nodes (1,1), (2,2) and (3,1). Predict laminar velocity profiles for a flow of two adjacent fluids inside a tube.

The above example problem is a typical textbook problem, however, before it was administered, author identified different concepts and concept levels (basic, moderate and advanced) and developed three concept group exercises and administered them sequentially.

**Concept group exercise 1 (basic)**
Water is accelerated by a nozzle to an average speed of 20 m/s and strikes a stationary vertical plate at a rate of 10 kg/s with a normal velocity of 20 m/s. After the strike, the water stream splatters off in all directions in the plane of the plate. If we have to set-up simple momentum balance equations, which forces will you take into account? Which non-zero velocity components will you consider in applying Navier-Stokes equation? How can you further simplify the equation with only one velocity component significantly changing with time and distance?

**Summary of student groups response**
Seven out of nine groups’ responses included rational flow design, simplified flow design with appropriate selection of velocity components and the unsteady state one-dimensional laminar flow equation, simplified version (see below).

\[
\rho \left( \frac{\partial V}{\partial t} + V_x \frac{\partial V}{\partial x} + V_y \frac{\partial V}{\partial y} + V_z \frac{\partial V}{\partial z} \right) = \rho g_y \cos \theta + \mu \left( \frac{\partial^2 V_x}{\partial x^2} + \frac{\partial^2 V_y}{\partial y^2} + \frac{\partial^2 V_z}{\partial z^2} \right)
\]
The class average of the basic concept group test was 40.6/50 (Figure 3a). The one-dimensional equation that students arrived at was the same equation that the author originally planned to ask them in their individual test. The author planned for the next slightly higher level concept exercise, which is elaborated below.

*Concept group test 2 (moderate)*

If the following grid (Figure 3b) is available to solve unsteady state one-dimensional laminar flow equation, can you write discretized algebraic equivalent? If intervals of ‘y’ and ‘t’ and kinematic viscosity are known, can you find out velocities at points (2,2) and (3,3)? How many equations that you will need to calculate velocity at point (2,2) if only $V_0= 3 \text{ ft/s}$ is known at the entrance, $y=0$?

**Summary of student groups response:**

As this was open book test, it was relatively easy for all the groups to provide the following equation-

$$V_{i,j} = V_{i-1,j} + \left( \frac{\nu \Delta t}{(\Delta y)^2} \right) (V_{i-1,j-1} - 2V_{i-1,j} + V_{i-1,j+1})$$

However, 6 out of 9 groups struggled to answer the third question in this category. This question required analysis, synthesis as well as evaluation. The author noticed a lot of reflecting activity, and reorganization of thoughts and concepts among the student group members throughout administration of this exercise. The average score on the exercise was 37/50 with a maximum and minimum of 42/50 and 30/50, respectively (figure 3a).

![Figure 3: a) Scores of different concept group exercises and b) rectangular grid describing subscripts i and j showing increases in x and y directions.](image_url)

The pretest average score of individual testing on the moderate exercise was 32/50, which is lower than the average posttest score of 37/50. This suggests about 10% improvement in overall learning by collaborative approach. Following this concept group exercise, the author demonstrated problem solving using the computational fluid dynamics software, COMSOL. Next, the advanced concept group test was conducted.
Concept group test 3 (advanced)
Using COMSOL create different meshes and report number of elements and predict laminar velocity flow profile of a fluid inside a tube.

Summary of student groups response:
Four out of nine groups did excellent job in creating different meshes and reporting number of elements. These groups also showed remarkable success in determining velocity values with position inside a tube. The average score on this test was 32.3/50. The scores of individual groups are shown in Figure 3a. Prior administrations of advanced group exercise, students were also tested on individual basis to demonstrate calculations using COMSOL. However, the average pretest score of the class was 27.5/50. By comparing the pretest and posttest results, overall improvement can be noticed, which is fairly consistent observation throughout this research investigation.

After administration of advanced concept group test, students were asked to solve Example 2 on an individual basis (posttest), which was based on the understanding of the concepts that they already learned as groups.

Posttest results:
Students individually performed calculations to obtain velocity at different nodes. In addition, students performed COMSOL modeling and extracted all the information, which is shown in the following Figures. They also successfully could locate the model window where the Navier-Stokes equations were listed.

![Figure 4: a) Flow profiles of water and transformer oil inside a tube and b) velocity as a function of distance.](image)

The posttest scores of individual students are shown in Figure 5, which indicates a maximum and minimum of 47/50 and 40/50, respectively with the class average of 45.4. Analysis of the test scores revealed that the students who participated in collaborative learning had performed significantly better than students who studied individually. This result is consistent with the learning theories suggested by collaborative learning supporters. Students are capable of performing at higher intellectual levels when asked to work in a group. This is again consistent with the fact that group diversity of knowledge and reformulating conceptual thinking has
positive effect on learning process. In a group, the peer support system makes learners inclined towards filling knowledge gaps, critical thinking skills and facilitating intellectual reflection of thoughts. In this study, the collaborative environment provided students with the opportunity to analyze, synthesize and evaluate their ideas through informal discussions and interactions. It is believed that students had to go beyond their opinion and provide judgments and reflections more concretely. The successful outcome of this effort was that the entire class attained the same level of understanding of the subject matter.

6. Conclusions

For the undergraduate Fluid Mechanics class, the average pretest score of one of the individual students’ tests prior conducting concept group exercise was around 29.9/50. To achieve continuous learning improvement, concept group exercises operating at basic, moderate and advanced levels were developed and routinely administered after every four lectures. These concept exercises were developed with the non-equivalent control design without taking into account the group influencing variables. In basic concept group exercise, a slightly higher score was observed as compared with advanced level concept testing. The assessment of these exercises revealed overall improvement in students learning ability, which was reflected in an average posttest score of 45.4/50. This study suggests that collaborative learning has improved the understanding of concepts among the students. It appears that the students developed better critical thinking skills through discussion, clarification of ideas and reflections of thoughts through social interactions.

7. References


