Guideline to an Effective Implementation of Student-Centered Learning in Engineering Education: Informal Cooperative Learning (ICL)

Article history
Received
19 Dec 2020
Received in revised form
29 Dec 2020
Accepted
29 Dec 2020
Published online
30 Dec 2020

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Abstract

The year 2020 witnessed several world transformations: from the new millennial of the 21st Century into the 4th Industrial Revolution, and now with the global pandemic of Covid-19. All these require educational transformations, especially in engineering. The challenging world requires new skills, particularly lifelong learning, complex problem solving and adaptability, the blurring systems of the 4th Industrial Revolution needs dynamic and integrated curriculum, and the global pandemic forces the extensive use of online learning. All these transformations, with respect to engineering education, requires the transformation of education from teacher-centered to student-centered learning (SCL), as outlined in the Outcome-Based Education (OBE). This paper systematically addresses how the transformation of engineering education can be achieved with effective implementation of SCL using a simple but just as powerful method, the Informal Cooperative Learning (ICL).

Introduction

The world today is more complicated than before. Nations of the world today are facing global challenges such as rapid technological development, exponential advancement in information and computer technologies, global sustainability, and knowledge economy. Now, the world is at the advent of the 4th Industrial Revolution - the age of cyber-physical system, in which technology is embedded into societies and human bodies with genome editing and machine intelligence (WEF, 2016). In 2020, the world is forced to live with new norms where Covid-19 pandemic has unleashed unthinkable changes. All these transformations call for new set of skills among professionals, especially engineers, where the presence engineering education cannot comprehend but to transform the education system into more student centered.

The pace of today's world is very fast. Information sharing becomes very easy, the rate of learning increased drastically, and the world feels like it is shrinking. To survive, younger generations, particularly engineering students need to adapt to these rapid changes or else they can be left far behind (Mohd-Yusof et al., 2015). The unprecedented scenario occurs because of various changes in terms of connectivity and competition.

The present information age signifies another context that higher education institution must seriously consider. The availability of the internet has resulted in information to be obtained easily and students are exposed to the abundant amount of data. Since globalization is the key trend that could not be denied, engineering students and graduates must be fully equipped with 21st century skills to stay relevant. They must be prepared and be able to work in a multi diversity team meritoriously.

To prepare students for this century, student centred learning (SCL) approaches are needed because the learning process will allow students to learn actively. The main principle in these methods is to allow and train the student circumscribe his or her own learning process. Subsequently, students can form their learning objectives and the methodology to pursue them (Osman et al., 2016). This approach could tackle the main challenge among engineering students to be adaptable leaners.

SCL techniques are conducted in class formally to escalate the development of important skills among engineering students. There are several approaches in SCL, among them are active learning, cooperative learning, and problem-based learning (Prince, et.al, 2013). Cooperative learning (CL) is one of the most sought-after method to foster the skill to work in a team among engineering students. It has proven to be a successful approach to build that character a student requires as an effective team player (Helmi et al., 2017, Smith, 2009).

CL involves group members creating individual contribution to maximise learning and achieve a common goal for the group (Ghazali et al., 2019, Smith, 2009). In the context of CL, an individual group member's success is contingent on the success of the group, and is carried out through individual responsibility, positive interdependence, and individual contribution (Johnson et al., 2014). However, the philosophy of CL implementation is more

than that as it can be further classified into differing structural categories that include formal cooperative learning (FCL) and informal cooperative learning (ICL) (Johnson, Johnson and Roseth, 2010).

FCL involves student cooperation and active communication that mostly revolves in the structured tasks instructed by the instructor, and usually takes place in several classes, whereas ICL involves the creation of small, ad-hoc groups so students can work together for shorter periods of time, usually one lesson (Johnson et al., 2014). A variety of techniques comprise ICL activities, such as Think Aloud Pair Problem Solving (TAPPS) and Think Pair Share (TPS), can be adapted to different levels of scaffolding to support the students in their construction of knowledge (Barkley, Cross and Major, 2005; Lyman, 1981). ICL is the easiest SCL approach to implement, but the question is, what is the principle behind it, and how to ensure its effective implementation? In view of this scenario, this paper intends to provide a practical guideline to more effective implementation of ICL which is an important block of SCL.

Student Centered Learning (SCL)

To cope with the massive transformations, the Future Jobs Report defined the 21st Century Skills (WEF, 2016), as shown in Table 1. The skills are divided into three domains: Foundational Literacies, Competencies, and Character Qualities. The foundational literacies are how students apply core skills to everyday tasks such as numeracy, scientific, ICT, financial and cultural. The competencies are how people approach complex challenges, such as critical thinking and problem solving, creativity, communication, and collaboration. The character qualities are how people approach their challenging world such as curiosity, intuitive, grit, leadership and social. Encompasses of all these domains is the life-long learning, which is to ensure the process of learn, un-learn, and re-learn.

Table 1. 21st Century Skills (World Economic Forum, 2016)

Foundational Literacies	Competencies	Character Qualities
Literacy	Critical thinking/ Problem solving	Curiosity
Numeracy	Creativity	Initiative
Scientific literacy	Communication	Persistence/grit
ICT literacy	Collaboration	Adaptability
Financial literacy		Leadership
Cultural and civic literacy		Social and cultural awareness
Lifelong Learning		

These transformations change the way we live, the way we do business, and the way we educate our engineers. The present teacher-centered learning needs to be changed towards student-centered so that all the necessary 21st Century skills can be well developed. This is more important especially in engineering education to ensure that our nation is not left behind in the face of technological transformations.

Based on suggestions given by stakeholders, the present education has successfully outlined the required skills needed for the transformation. One of the initiatives is the Outcome-Based Education (OBE). Nevertheless, by outlining the skills alone is not enough. These skills are difficult to instill if there is no clear guideline on how to support the development. For example, to ensure the intended outcomes are attainable, the learning outcomes in the OBE curricula must be constructively aligned with teaching and learning, and assessment (Biggs, 2011).

The past president of the Carnegie Foundation for the Advancement of Teaching, Professor Lee Shulman, wrote what it looks like when learning does not go well (Shulman, 1999). In this paper, he highlighted the "taxonomy of pedago-pathology" consisting of 3 sicknesses among his medical education students: amnesia, fantasia, and inertia. According to Shulman, amnesia refers to students totally forgetting what they learned, to the extent that they even forget they attended some courses. Fantasia refers to persistent misconceptions, where students are unaware that they have misunderstood certain key concepts. This sickness is even more dangerous than amnesia, especially for professionals. Inertia denotes inert knowledge, where students are unable to apply what they learned, although they may well be able to explain them and answer examination questions well. The students might have good grades in his study, but when it comes to practice, he is unable to apply what he learned. This is one of the reasons why there are so many complaints from industries towards new graduates.

To ensure that students meet the challenges of the 21st century by acquiring higher order thinking skills, as reported by Kim (2016) and Yen and Halili (2015), SCL implementation is the required. The concept of SCL, as stated by Overby (2011), is to "bring the classroom and students alive". To make the classroom real. This is in line to Uhl's (2010) statement that SCL is "the power to transform classroom from tedious, lifeless places to alive, authentic relationship-rich environment".

The transformation from the conventional Teacher-Centered Learning (TCL) environment to SCL environment is aligned with the needs of OBE to gain meaningful outcomes mainly the 21st Century Skills. The teaching and learning approaches should move beyond the content to help students construct their own self-concept as a lifelong learner and agent of the transformation. However, even though many countries encourage the use of SCL approaches that emphasize on OBE, most engineering instructors still utilize TCL approaches (Felder, 2003; EAC, 2020). Many are not equipped with effective teaching skills,

especially SCL. Although academic staff have been trained to conduct research during their studies, there was hardly any guidance in how to effectively teach and design a conducive learning environment. Studies by Geven and Attard, (2012), and Mohd-Yusof, et.al, (2018) have proven that the acceptance of SCL implementation among students and instructors in engineering has given a positive impact to improve instructors' teaching. Unfortunately, it is common for lecturers to think that SCL is difficult to implement.

The Student-Centered Learning Continuum

As a guideline to the degree of instructor centered versus student centered in SCL, Lord, et.al, (2012) had proposed a representation of SCL continuum. There are various techniques under SCL, ranging from approaches that are easy to implement and high degree of instructor's control, to complex and high degree of students control, as in Figure 1. Referring to the figure, the approaches on the left are more instructor's control and are more easily accepted by instructors and students who are used to traditional teaching approaches in the form of TCL. The approaches that are more to the right have a higher degree of student control, responsibility, and ownership, more towards SCL, and would require instructors to have good facilitation skills. The following are some examples for different categories of instructor's towards increasing students' control:

- *Category 1* – instructor makes the class active by involving students in the classroom such as by asking randomly students' opinion.
- *Category 2* – instructor, by design, used structured collaborative activities to engage all students in the classroom in learning activities such as Read and Explain Pairs (Johnson, Johnson and Smith, 1998) and Pair Composition (Steendam, et.al, 2014).
- *Category 3* – students involved in a formal, team-based learning activities, such as Cooperative learning (Johnson, Johnson, and Smith, 2013) which requires more students' commitment to Learning. Instructor plays the role as facilitator in performing activities to form deep understanding and positive attitude among students.
- *Category 4* - the degree of students' control is the highest but requires proper preparation from the instructor and students' learning commitments. It uses more complicated approach, such as Problem-Based Learning (PBL), which is able to develop not only the cognitive and conceptual domains, but also to shape the affective domain in terms of attitudes (Helmi, et.al, 2017; Mohd-Yusof et.al 2013). This category requires instructor with good skills as a facilitator to scaffold students in the learning process.

The aim of this paper is to explain the fundamental concept of SCL at category 2, which is also the basis for implementing learning approaches at category 3 and category 4. The basic concept of activity under category 2 learning approach will be described to enable the design of new activities to suit the learning outcomes and the desired new methods. This can be used as a guideline to an effective implementation of SCL in Engineering Education to encourage faculty members to try simple SCL approaches they can start off with, that will not be time consuming in planning and implementation. From these easy to implement but effective SCL activities, instructors can then develop the interest and confidence to venture into more complex and elegant methods in their classes.

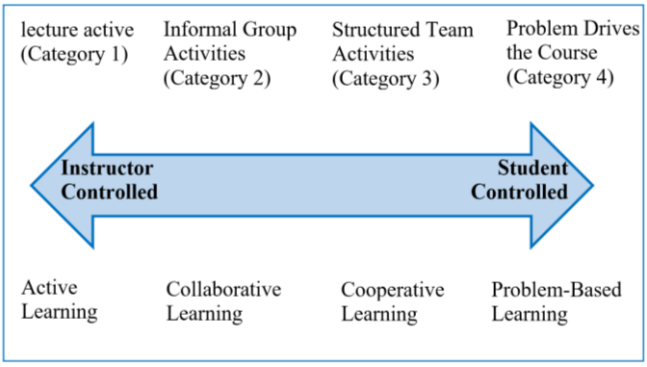

Figure 1. The student-centered learning continuum (Lord, 2012)

Informal Cooperative Learning

Lord (2011) named Category 2 as Informal Group Activities. It is also known as Informal Cooperative Learning (ICL) (Johnson, Johnson, and Smith, 2013). It is called "informal group" since it is an ad-hoc group that is form at any time while learning in a class, to perform structured active learning activities. While "formal group" is a long-term group ranging from one class to one semester that may perform longer structured activities. The main aim of the ICL activities is to engage students in learning. The following are some of the other reasons of using ICL (Felder, 2005):

1. To set a mood conducive to learning.
2. To help organize in advance the material to be covered in a class session.
3. To ensure that students cognitively process the material being taught.
4. To focus students' attention on the material to be learned.

The Bookend Division

There are many active learning activities that can be done to engage students in learning in the implementation of this ICL learning process. These activities can be divided into 3 types: (1) advanced organizer, (2) intermittent discussions, and (3) closure. One of the instructional designs that are easy to apply to ensure a smooth and effective implementation of these active learning activities in a classroom is called "the bookends division approach" (Smith, 2009). Figure 2 shows the design for a 50-minute lesson plan based on the bookends' division approach.

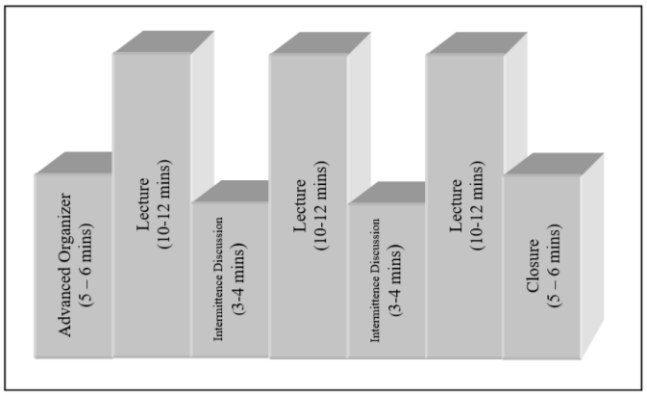

Figure 2: Bookend Division Instructional Design

1. Advanced Organizer

As illustrated in Figure 2, teaching starts with opening activities as the Advanced Organizer, for about 5 to 6 minutes. This opening activity is very important to provide a conducive environment and set the mood for students' learning. It is also used to identify the existing knowledge of the students on the topics to be taught to help them link the existing knowledge with newly learned knowledge. According to Ausubel (1968), "the most important single factor influencing learning is what the learner already knows. Ascertain this and teach them accordingly". Among the opening activities that can be done are Opening Question (Canady and Rettig, 2013), Brainstorming (Osborn, 1953, rev. 1957, 1963), and Focused Listing (Specht, 2019).

2. Intermittent Discussions

Once the advanced organizer is done, it is followed by a short lecture. To ensure that students give full attention to the lecture, at around every 10 to 12 minutes, the lecturer needs to insert activities as the Intermittent Discussion for about 3 to 4 minutes. By listening to the students' discussion, the teacher will be able to find out if there any mistake in the understanding of the students and correct their mistakes in the topic they are studying. These activities also aim to help students to gain deep understanding of high-level thinking, as well as to retain longer of what they had learned. Among the activities that can be done are Note Checking (Johnson, Johnson, and Smith, 1998), Pair Testing (Black and William, 1998), and Question and Answer Pairs (Sasaki, 2005).

3. Closure

At the end of the lecture there should be a closing summary activity as the Closure for about 5 minutes. The purpose of the closure is to make a final summary and ensure that students understand what they learned during the class time. It also aims to make early preparation for students to attend the next lesson at the upcoming meeting. Among the activities are Two-Minute Paper (Felder and Brent, 2005), Closure Review Pairs (Johnson, Johnson and Smith, 1998), and One Final Question (Shweta, 2011).

The Informal Cooperative Learning Structures

In the traditional class when the instructor asks the students, "does anyone have any questions from last time?" Most of the time the students refused to ask questions even though the lecturer encourage questioning. So, what is the solution to this? One of the ICL activities to overcome this is called Think Pair Share (Lyman, 1981) as illustrated in Figure 3. As shown in the Figure, the instructor poses a question to the class and the students think about their response individually. Then, the student pair with a partner (or in a group of 3) to talk over their ideas. Finally, the students share their ideas with the whole class. This is a very simple activity, which will take about 3 to 4 minutes. However, this simple activity is so impactful since it engaged and involved all the students in the class. There are many other ICL activities similar to this. All these activities are designed according to the pattern shown in Figure 4 (Mohd-Yusof, 2017).

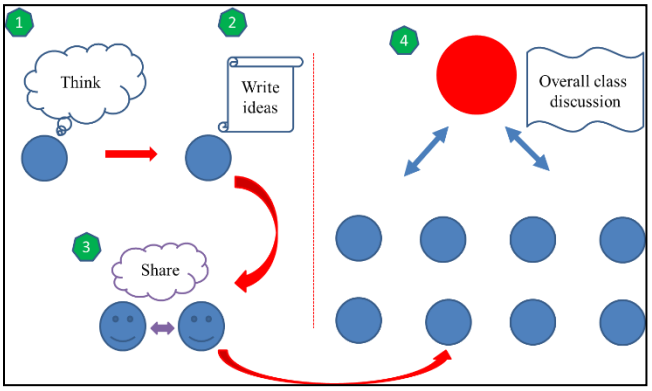

Figure 3. Steps in Think-Pair-Share - ICL Activity

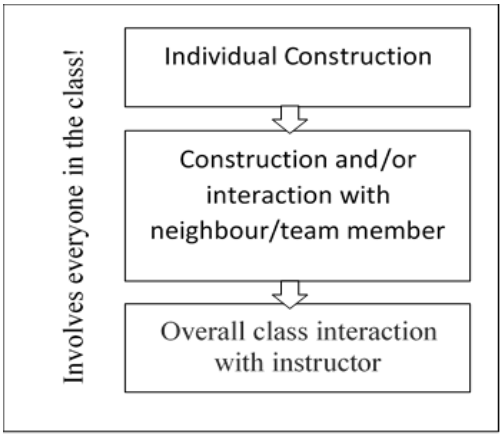

Figure 4. Informal cooperative learning pattern

By applying this pattern in the ICL activities the instructor is able to engage all students in class, without exception. These activities always start with individual construction where the students will think by themselves to answer questions or perform tasks that are given by the instructor. After individual construction, students are asked to share their efforts with their neighbours or in teams. By giving the opportunity for the students to think by themselves first, they are given the chance to construct their own

ideas. Thus, every student has some ideas to share with their neighbour or team members. Therefore, the discussions will be more meaningful. After discussing with their neighbours or in teams, the discussion is open for the whole class facilitated by the instructor. Discussions at this time will be more interesting and interactive. However, the duration of each activity should not be too long and should be under the facilitation of the instructor. The recommended duration for each activity is between 3 to 4 minutes. One important thing to remember is that each of these activities must be conducted with a purpose and needs to be planned to achieve the best results. The objectives and the outcomes of the activities should be informed to the students so that they understand what they need to do to get the benefit from the activities.

The Bookend Division on Online Informal Cooperative Learning

For online ICL, it is more important to make the teaching interactive since it is conducted virtually, and both the instructor and the students are not physically present. However, since the Covid-19 pandemic, there are many remote teaching platforms and tools available to ensure students' engagement in learning. It is important to use SCL approaches for the class to be interactive, whether it is conducted in synchronous or asynchronous modes. The virtual space such as Zoom, Webex, or Google Meets has many "facilities" to ensure the students engagement in learning such as the Chat Room, the Breakout Rooms, Reaction, the Share Screen, Poll, etc. Apart from the virtual spaces, there are also many learning tools available to support the active learning in remote classrooms such as Kahoot, Socrative, Google Jamboard, Mentimeter, etc. All these virtual spaces and online tools bring new opportunities for active learning and student engagement.

This even more important because these activities can create social presence, which is important in supporting the classroom community to create a positive environment in the virtual classroom, helping students feel less isolated. Nevertheless, to ensure the effectiveness in learning, the Bookend Division approach, the ICL activities, and the ICL pattern must still be applied and are still the same. The only difference is the time duration at each scenario. Figure 5 shows the Online Bookend Division approach with the suggested time duration, since the time taken to get students' response will normally be delayed. Figure 5 shows the design for 1hour and 30 minutes lesson plan based on the Online Bookend Division approach. As shown in the Figure, there is only one Intermittence Discussion for the entire 1.5 hours online class. This is because longer duration is needed for each online active learning activity. The other two (2) active learning activities in the Bookend Division are the Advanced Organizer activity and the Closure activity.

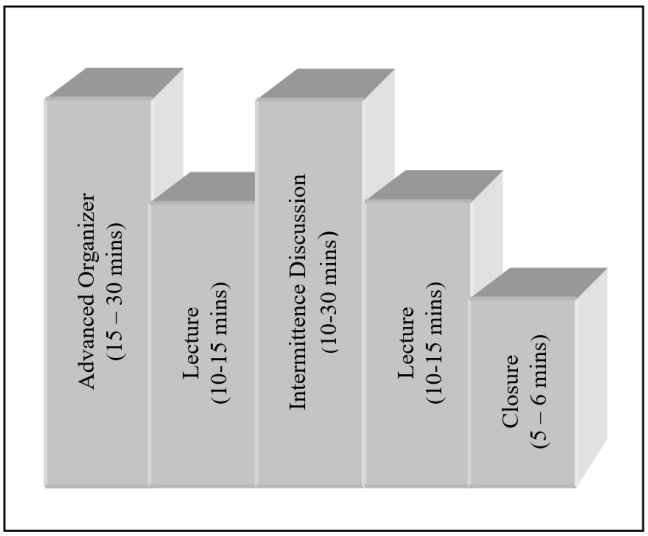

Figure 6. Online Bookend Division Instructional Design

Discussion and Conclusion

With the challenges of the 21st Century, the advancement of the Industrie 4.0, and the Covid-19 pandemic, the year 2020 is full of transformations. Global challenges require global solutions with skills suitable for an uncertain world. In Industrie 4.0 many existing jobs will be replaced by computers and robots, while many new jobs will emerge. These new emerging jobs require high creativity that computers and robots are not able to replace, the ability to adapt and adopt, to learn, un-learn, and re-learn. The global pandemic causes the extensive use of digital systems, online learning, virtual classrooms, and virtual laboratories.

All these require the transformation in education, especially engineering education. Education should nurture students to obtain deep understanding rather than just memorizing. Thus, the SCL approach needs to be taken seriously. In Bloom's Taxonomy, if teaching only using the traditional way, which is mere lecturing, then the highest level of Blooms' that can be achieved is only at the surface understanding, which is at level 1 (Chi, 2009)

The ICL activities pattern provides a framework for lecturers to design their own activities that are suitable for their own classes to fit the outcomes that they intend. The specific ICL activities provide some common techniques that can be used either as Advanced Organizer, Intermittent Discussion or Closure. Choosing or designing the appropriate ICL activities depends on the desired outcomes. As recommended in the principle of constructive alignment (Biggs and Tang, 2011), the active verb in the outcomes should be activated in the teaching and learning activities in the classroom to give the students a chance to construct their understanding at the appropriate level of outcomes. As such, the ICL activities can also be used as scaffolding for learning to support students to reach higher level outcomes. To be a part of the transformation agent, engineering instructors should adopt SCL method. Based on this

method, the easiest approach to practice, but promising good results, is by using the ICL approach. This approach is systematic and easy to implement at any time, under any circumstances, even remote classes during the Covid-19 pandemic.

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