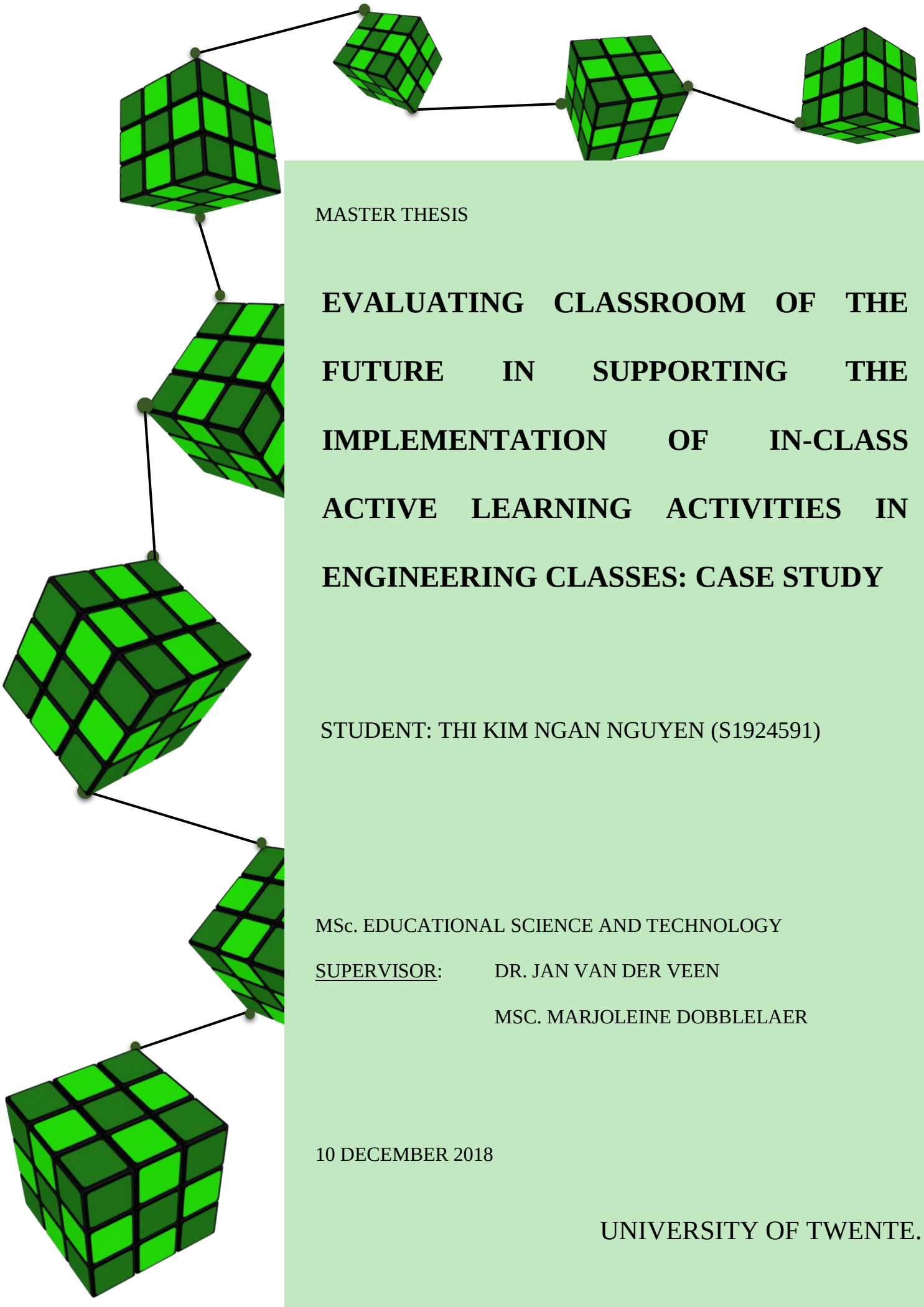


MASTER THESIS

EVALUATING CLASSROOM OF THE FUTURE IN SUPPORTING THE IMPLEMENTATION OF IN-CLASS ACTIVE LEARNING ACTIVITIES IN ENGINEERING CLASSES: CASE STUDY

STUDENT: THI KIM NGAN NGUYEN (S1924591)

MSc. EDUCATIONAL SCIENCE AND TECHNOLOGY

SUPERVISOR: DR. JAN VAN DER VEEN

MSC. MARJOLEINE DOBBLELAER

10 DECEMBER 2018

UNIVERSITY OF TWENTE.

Master of Science in Educational Science and Technology

University of Twente, Netherlands

Evaluating Classroom of the Future in Supporting the Implementation of In-class Active Learning Activities in Engineering Classes: Case Study

Student Name: **Thi Kim Ngan Nguyen**

1st Supervisor: Dr. Jan van der Veen

2nd Supervisor: MSc. Marjoleine Dobbelaer

Author Note

Correspondence concerning this article should be addressed to Thi-Kim-Ngan Nguyen, Faculty of Behavioral, Management and Social Sciences, University of Twente, P.O. Box 217, 7500 AE Enschede, The Netherlands. Phone: 0649260054; E-mail: nguyenthikimngan@student.utwente.nl

Table of Contents

Acknowledgement

I had a long hard time figuring out who I was and what my purpose in this life was. However, since I came to the University of Twente to follow the Master of Science in Educational Science and Technology, I had many chances to meet inspiring people and see the world, through which, I also know more about myself and what I want to pursue in my life. Therefore, this thesis is not only the final project of my Master program, but also the milestone that marks the end of the journey, in which, I learnt, grew, and gained back confidence in myself. Now that I have almost finished the program, I am thankful for all the experiences that the EST program and the University of Twente offered me as a student. These valuable experiences and knowledge will definitely be helpful to me in my future career as well as personal life.

This thesis is also an exciting adventure, where I made the decision to try something brand new to me, with the belief that a new field would come with unexpected amazing things. Trying new things also means more challenges due to lack of experience. Luckily, I had the best supervisor, Prof. Dr. Jan van der Veen, who was always highly responsible, thoughtful and enthusiast in helping me with every little issue during the completion of this project. Nothing can express my great gratitude to him. Thanks also to the second supervisor, Marjoleine Dobbelaer, for taking the time to read my thesis and suggesting ways to make it better. Thank you, Dr. Frank Kresin, Miriam Illiohan, Wytze Koopal, Charlotte Oude Alink and Dream Team. Without your support and valuable information, I could not have completed my final project.

Furthermore, I would really like to thank my Vietnamese friends in Enschede: Đạt, Mai, Tuấn, Việt Anh, Nghĩa, anh Hải, chi Hòa, anh Thành…, who helped me to overcome the difficulties during my stay here and contributed to my wonderful memory in the Netherlands. Thanks also to all my friends in Vietnam: Sơn, Uyên, Đoàn Hiên… who listened to my troubles and cheered me on through hardship. I especially thank Như, my roommate and little sister, who took care of me and loved me ‘unconditionally’.

Finally, I would like to express my deepest gratitude to my parents. Thank you, ‘Bố’ and ‘Mẹ’ for giving me your whole life and your perfect love. You always treated me like I am a 3-year-old baby. I hope by now, you have realized that I have grown up, so you don’t have to worry about me anymore. I hope by now, your ‘little’ daughter has made you happy and proud of her.

Summary

In engineering classes, active learning is considered superior because this method increases students' learning result and improves their social skills. Keeping in mind the advantages of active learning, it is necessary to support teachers and students to implement active learning activities in classes. The University of Twente created an innovative learning space called Classroom of the Future, which is favorable for implementing in-class learning activities. Yet, the effectiveness of the Classroom of the Future has not been evaluated and confirmed. Therefore, this study aims to investigate in what ways the Classroom of the Future facilitates active learning and what hinders the effectiveness of the Classroom of the Future. This study is a cross-case study research, which involved information from the Classroom of the Future, interviews with teachers, surveys with students and class observations. The results of this study provide recommendations to improve the effectiveness of the Classroom of the Future, specifically in supporting the implementation of in-class active learning activities. The results can also be an important input for designing future learning spaces.

Key words:

In-class Active Learning Activities, Innovative Learning Space, Engineering Education

1. Introduction

Classroom of the Future at the University of Twente is an innovative learning space created to facilitate active learning. The Classroom of the Future is a test ground for technology in education. The success of this project can be what the University of Twente would look like in a few years. Therefore, to ensure that precise decisions are made in future campus design, it is necessary to evaluate the effectiveness of the Classroom of the Future to determine which elements should be improved, which features should be changed, or which facilities should be supplemented.

The project evaluation includes the assessment of how the Classroom of the Future has been supporting teaching and learning, the analysis of stakeholders' needs and the cooperation with University Innovation Fellows to explore new interventions. As part of the evaluation of the Classroom of the Future, this research aims at investigating to what extent the Classroom of the Future facilitates or hinders the implementation of active learning activities, targeting engineering teachers and students.

The structure of this thesis is as follows: In part one, the context will be presented. In part two, the problem statement will be described. From that, research questions are given. Part three entails the theoretical framework. Part four involves the evaluation framework, which served as the basis of the evaluation and the creation of instruments. In part five, the research design is provided. Detailed results of each case will be described in part six. Part seven will be the discussion. Finally, part eight presents the conclusion and recommendations.

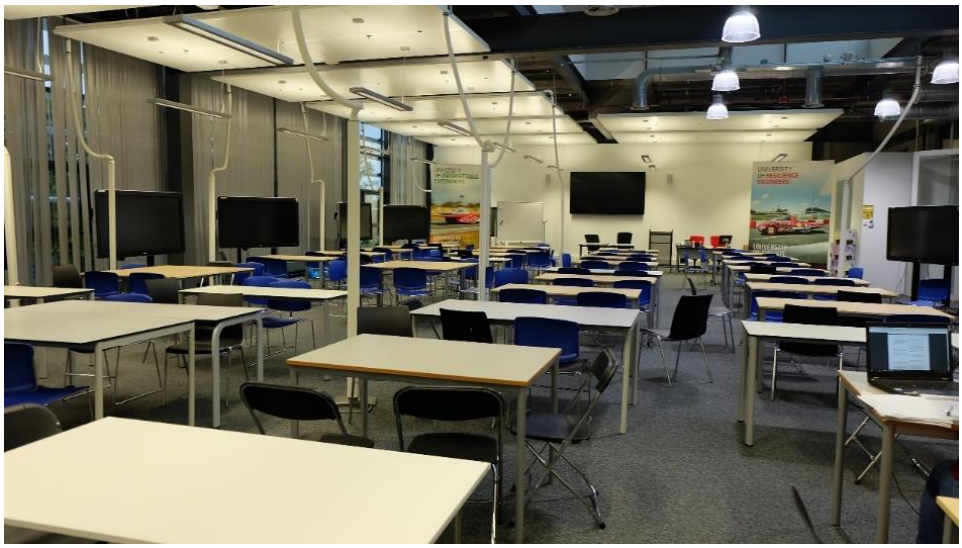
1. Context

Classroom of the Future was initiated in February of 2015 by Professor Jos van Hillegersberg at the University of Twente, as a 'collaborative educational space influenced by technology' for interactive education (de Kuyper, 2015). The Classroom of the Future was designed and created with the goal to optimize the usage of modern and effective didactical methods in education to enhance team collaboration. Classroom of the Future was created in line with The Twente Education Model (TEM) for all undergraduate programs, which emphasizes on project-based work and student-driven learning. The model seeks to combine perspectives from sciences and social sciences, which respect to the conceptual development of students as well as developing skills and attitudes ("Classroom Of The Future," n.d.).

From July of 2018, the ownership and management of Classroom of the Future was placed with DesignLab, after three years of operation under LISA (Kuipers, 2018). To mark this new milestone and to move on to the next phase, a plan to improve the effectiveness of this innovative learning space in supporting teaching and learning has been launched. To reach that end, an evaluation serving as a basis for the development plan has been conducted since the beginning of the academic year 2018.

Description of the Classroom of the Future. The Classroom of the future offers room for about 120 students. There are forty tables. Twenty of the tables with two wheels each, together with 120 light chairs that can be moved easily. With flexible furniture and spacious space, the room can be changed to suit different learning purposes and scenarios, from plenary space for whole class learning (see figure 1) or group space for six students in each group (see figure 2).

Figure 1



The plenary space of the Classroom of the Future for whole class learning

Figure 2

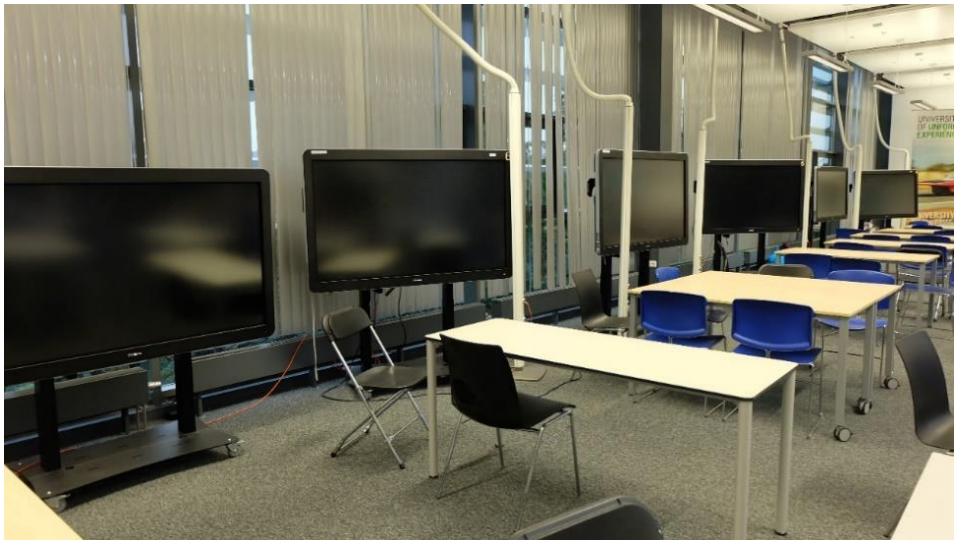
Setup for groupwork in the Classroom of the Future

The technology in Classroom of the Future includes a main LED screen for presentations or showing videos (see figure 3), sixteen 65-inch interactive screens that can be moved around the classroom (see figure 4). The interactive screens can be connected to the main LED screen to show the presentation simultaneously. These interactive screens can also be connected to students' laptops for students to create and share their products between group members or with teachers and other groups.

Figure 3

The main LED screen in the Classroom of the Future

Figure 4



The movable interactive screens in the Classroom of the Future

As part of the Classroom of the Future, an information letter (see appendix A) is sent via email to every teacher who registered to use the Classroom of the Future prior to their classes. The information letter is a two-page document, in which, the purpose, setup and, technology of the Classroom of the Future is briefly described. First, it is stated that the Classroom of the Future is aimed at stimulating active (group) learning, by facilitating student interaction, interaction among students in a group (collaboration) and interaction between/among groups. Second, the interactive screens and main LED screen are listed among the technology that the teachers can use in the Classroom of the Future. Technical assistance is also available when the teachers need to use the screens. Finally, pictures of two different setups of the room, including whole class learning and group work, are included.

Similar projects in technical universities

Classroom of the Future is inspired by the LKCS studio classroom, located in Stanford University, with comparable setup and gadgets (see figure 5). LKCS studio classroom is a large, flat-floored space, which can be divided and is equipped with moveable tables and chairs and multiple screens around the room to support team-based and small-group learning (“Medscheduler”).

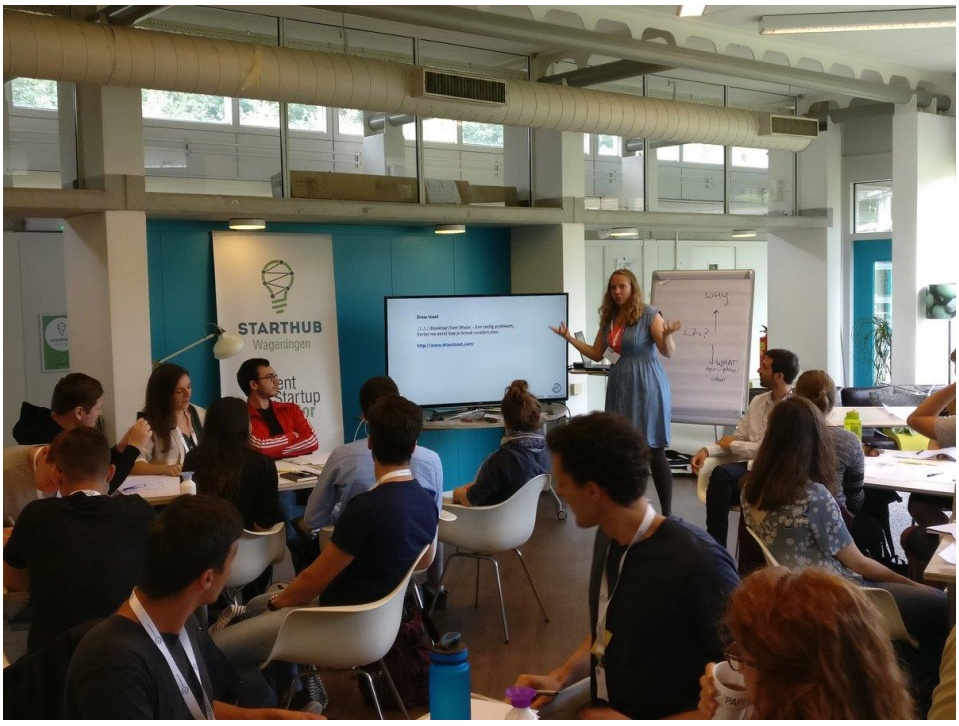
In the Netherlands, among the research universities, University of Twente, TU Delft, TU Eindhoven, and Wageningen University and Research Centre are specialising in technological fields. Therefore, the four universities are working together in the 4TU. Centre for Engineering Education (4TU.CEE). In the field of innovative learning space, each university is developing a space similar to DesignLab, for instance, D:Dream Hall at TU Delft, Plus Ultra at Wageningen University, and Innovation Space at TU Eidnhoven. Comparable

project to the Classroom of the Future can be found at Wageningen University under the name StartHub (see figure 6). StartHub Wageningen is the incubator for start-ups of qualified Wageningen (PhD) students. It offers flexible and interactive working space for workshops and events to develop students' entrepreneurial skills ("Student Incubator," n.d.).

Figure 5

LKCS studio classroom at the Stanford University

Figure 6



StartHub at Wageningen University

2. Research problem

2.1. Problem statement

In the search for the effective way of learning, Biggs (2003); Najafi, Motaghi, Nasrabadi, and Heshi (2016) believed that students acquired their knowledge best by approaching actively to learning. In addition, LoPresto and Slater (2016) suggested that students gained greater learning when they engaged in activities. As a result, active approach will result in students' better learning achievement compared to regular lecture (Ralston, Tretter, and Kendall-Brown, 2017). In other words, it was implied that active learning was a scenario favorable for students to acquire knowledge. According to Felder and Brent (2009), "*active learning is anything course-related that all students in a class session are called upon to do other than simply watching, listening and taking notes"* (p. 2). Collaborative learning, cooperative learning, and problem-based learning are all categories of active learning (Hyun, Ediger, and Lee, 2017). More specifically, students can learn actively by participating in various in-class active learning activities (IALA), such as quiz or poll (Steadman, 2015), problem-solving tasks (Wismath and Orr, 2015), presentation (Lagares and Reisenleutner, 2017), debate (Najafi et al., 2015), discussion (Seechaliao, 2017), jigsaw project (Karacop, 2017), etc.

Particularly in engineering programs, IALA are proven to bring critical benefit (Wiggins, Eddy, Grunspan, and Crowe, 2017). IALA increase engineering students' motivation to learn compared to regular lecture (Knight, Carlson, and Sullivan, 2007). As a result, students gain greater learning (Lopresto and Slater, 2016) and achieve higher in exam activities (as cited in Wiggins et al., 2017). Besides, IALA are the most appropriate strategy in preparing engineering students for the future career (Gol and Nafalski, 2007) because IALA give students opportunities to improve interpersonal interactions, self-esteem, attitudes, and social skills (Ralston et al., 2017). Therefore, engineering students should be given more opportunities to engage in active learning.

However, passive learning is still dominant in classes, especially in higher education (Ralston et al., 2017). This passive learning style is not only the least engaging and motivating method (Chi and Wylie, 2014) but also fails to support students in gaining skills. That is part of the reason why CDIO (Conceive – Design - Implement – Operate), an innovative educational framework for producing the next generation of engineers, recognized that engineering education has increasingly distanced from real-world demands, as graduating students, while technically competent, lack many skills (Berggren et al., 2003).

Among the reasons which hinder its implementation, it was reported that teachers needed more time and effort to design activities considering the fixed setup of traditional classrooms (Hyun et al., 2017). Therefore, teachers prefer classrooms which support learners to engage actively with their learning and to collaborate with the others (Pedro, 2017). To that end, innovative learning spaces have been designed to make it easier for teachers and students to implement IALA.

There has been evidence that innovative learning spaces are crucial in implementing IALA. Chiu (2016); Granito and Santana (2016); Hyun, Ediger, and Lee (2017) explained that innovative spaces encouraged collaboration and interactions. Consequently, students having IALA in innovative spaces were reported to perform better than in a traditional classroom (Brooks, 2012). As a result, students view the innovative learning environment as advantageous (Ünal and Çakir, 2017) and prefer innovative learning space to traditional classroom when they implement IALA (Dori and Belcher, 2005; Beichner et al., 2007). To conclude, Stoltzfus and Libarkin (2016) suggested that learning space is an important factor influencing the implementation of IALA. Nevertheless, there are conflicting opinions about whether innovative learning spaces facilitate IALA. Stoltzfus and Libarkin (2016) found no significant difference between innovative learning space and traditional classroom in the impact on students' actual performance. Smith, Higgins, Wall, and Miller (2005) suspected if the benefits were from uncritical bandwagon effect.

Similarly, the Classroom of the Future was designed to support active learning at the University of Twente, a technical university in the Netherlands. Yet, the effectiveness of the Classroom of the Future remained unclear. Therefore, this research aims at providing insight on how the Classroom of the Future supports the implementation of IALA in engineering classes. This goal was achieved by observing classes, interviewing teachers and conducting survey on students. Based on the results, suggestions were made on further supports so that teachers and students can use the Classroom of the Future effectively when implementing IALA.

2.2. Research questions

This research attempts to answer the research question "How to improve the effectiveness of Classroom of the Future in supporting the implementation od in-class active learning activities in engineering classes?"

To answer the main research question, the following sub-questions will be addressed

1. In what ways does the Classroom of the Future facilitate the implementation of IALA in engineering classes?

2. What hinders the effectiveness of the Classroom of the Future in supporting the implementation of IALA in engineering classes?

2.3. Scientific and practical relevance

This research is important because of several reasons. In terms of scientific relevance, although more attention has been paid on learning spaces which facilitate active learning since technology witnessed massive change (Parsons, 2017), the influence of innovative learning space is still a relatively new field of study (Sawers, Wicks, Mvududu, Seeley, and Copeland, 2016). There were few researches on impact of learning spaces on teaching and learning (Granito and Santana, 2016), and most of them focused on how innovative learning space impacted teaching and learning, rather than how teachers and students experienced and commented on the innovative learning space (Granito and Santana, 2016), Therefore, this research examined teachers and students' attitudes towards the innovative learning space to contribute to the ground knowledge of this topic.

In terms of practical relevance, the learning environment plays a central role in education, particularly in higher education (Harvey and Kenyon, 2013). Therefore, the usefulness of Classroom of the Future should be evaluated carefully so that it can be used in the most effective way to support teaching and learning. Second, this research provides essential data to help the University make decisions on future learning space design. Finally, Classroom of the Future was expected to be the prominent model of the whole campus in a few years. Thus, the management team of Classroom of the Future hoped that the success of this project would give valuable ideas on future learning space design so that different learning purposes would be assigned to classrooms with suitable functions instead of simply the suitable number of seats.

3. Theoretical framework

3.1. Space in the innovative learning space

To facilitate IALA, teachers are expected to give students freedom and act as a guide by giving advice, feedback, maintaining close contact, monitoring progress in active learning (Gol and Nafalski, 2007; Knight et al., 2007). To do that, teachers should be able to move close to students and walk freely around the classroom to engage with individual students without physical obstacles (Chiu, 2016). Therefore, the front instructor area, as well as the physical barrier should be eliminated so that teacher could approach freely to each student in class for guidance and support during group work (Chiu, 2016; Granito and Santana, 2016).

Moreover, the opened workspace in the classroom is important. To students, the space should allow them to spread out instead of being cramped because of too many tables. To teachers, the space should be wide enough for them to walk around to check on students (Granito and Santana, 2016). Therefore, innovative learning space should offer a spacious workspace for both teachers and students (Sawers et al., 2016).

Space in the Classroom of the Future is spacious with only students' small tables and single chairs in the classroom, which allows teachers to move freely and interact with students. Therefore, the space in the Classroom of the Future is hypothesized to allow free interaction between teachers and students.

3.2. Furniture in the innovative learning space

Felder and Brent (2009) suggested that time given on each IALA should be from fifteen seconds to three minutes, and there should be several learning activities throughout the lecture. To that end, the flexible furniture in the innovative learning space is reconfigurable for different learning scenarios and learning purposes (as cited in Chiu, 2016). The flexible furniture allows students to quickly switch from lecture to activity and back. As a result, chairs and tables with wheels for flexible setups are preferred by both students and teachers (Granito and Santana, 2016). Students emphasized that without movable chairs and tables, their performance of active learning would have suffered (Stoltzfus and Libarkin, 2016). In addition, contrary to passive learning when students mostly work alone, active learning often requires students to work with each other. Thus, flexible furniture is preferred because it fosters interactions (Stoltzfus and Libarkin, 2016). Flexible furniture can be formed as round-table so that students can sit together, brainstorm, conduct activities, participate in group discussions and conduct cooperative learning activities (Chiu, 2016). Round-table encourages interactive learning

because it allows eye contact, hand gestures, nonverbal communication which are essential for exchanging information between students, and allows immediate feedback (Parsons, 2017).

Instead of long and heavy tables, tables in the Classroom of the Future are light and small for two people. Moreover, twenty of the tables have two wheels each, which makes them easy to be moved around for different learning purposes. When putting two tables together, a bigger table for six to eight people to sit around is created. Therefore, the flexible furniture in the Classroom of the Future is hypothesized to enable peer interactions.

3.3. Interactive screen in the innovative learning space

To support intra-group interaction, the interactive screen can be used to share information between group members (Hyun et al., 2017). For instance, some students can work at the screen while others work from the laptop to contribute to the same product (Bell, 2002), making the interactive screen an effective tool for students to collaborate and discuss (Beauchamp and Parkinson, 2005). In addition, at the end of the activity, the result of the groupwork can be printed, distributed or saved for future work (Bell, 2002).

To promote inter-group interaction, the interactive screen can support communication and productive talk (Kershner, Mercer, Warwick, and Staarman, 2010). It is because the interactive screen can be used as a wireless presentation screen offering an interactive, visual experience, and a 'dialogic space' in which diverse opinions, perspective, products are presented (de Silva, Chigona, and Adendorff, 2016), which means different groups can show their presentation on the interactive screens at the same time.

In terms of interaction between students and teacher, the interactive screen could create a favourable environment in several ways. First, teachers can show the information on the big screen simultaneously on interactive screens placed throughout the class. As a result, the interactive screen helps classes to become immersive and engaging to students (de Silva et al., 2016). Also, the teacher can move around the class keeping track with the main content and control over the lesson. Without the interactive screen, the teacher may physically attach to the main screen instead of the students (Wood, 2001). Third, teachers could distribute different challenges to different groups (Beauchamp and Parkinson, 2005). This way, each group can work in a different problem or topic, so that the presentation of the whole class will be diverse and engaging. Finally, the teacher can station at the computer and students offer suggestions and contribute actions directly through the interactive screen (Bell, 2002). Also, the interactive screen allows teachers to give immediate feedback to students during IALA (Glover, Miller, Averis, and Door, 2007).

To sum up, interactive screen in the Classroom of the Future is hypothesized to enable easy information sharing intra-group, intergroup and between teachers and students.

3.4. Pedagogy, technology and innovative learning space

Innovative learning space includes advanced and specialised features. Among them, the interactive screen was the least familiar, or even the only unfamiliar tool, to teachers, compared to space, furniture or main LED screen; Therefore, the interactive screen might pose more difficulties for teachers and students. Since resources are active only as they are used (Cohen and Ball, 2001), the presence of the interactive screens does not guarantee that they will be used in a proper way to serve the learning purposes.

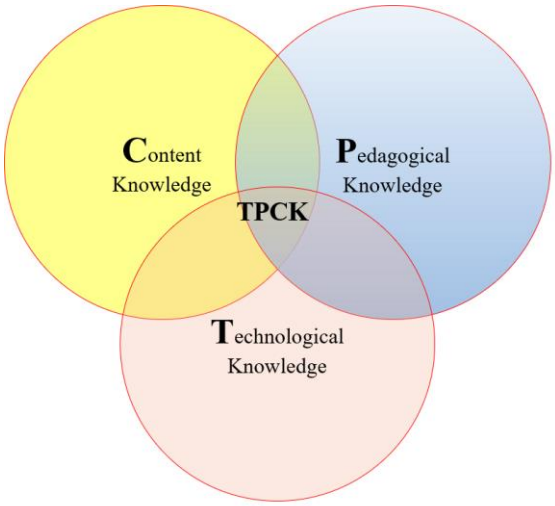
Among the external and internal factors influencing the use of technology, Ertmer, Ottenbreit-Leftwich, and York (2006); Ertmer, Ottenbreit-Leftwich, Sadik, Sendurur, and Sendurur (2012) found that teachers' own attitudes and beliefs were the most influential factor. More particularly, teachers should have beliefs towards the relevance of technology in education (Gobel and Kano, 2013) and belief that technology will benefit their teaching and their students' learning (Habibu, Abdullah-Al-Mamun, and Clement, 2012). Gilakjani (2013) explained that attitudes and beliefs served as motivation for teachers to devote extra time and effort to integrate technology in teaching and learning. In contrast, teachers' resistance to use new technology would be a significant problem in integrating new tool in education (Habibu et al., 2012). To that end, the best way to promote teacher's belief towards technology is increasing teacher's knowledge of how technology can be used to benefit teaching and learning (Ertmer et al., 2012). Tambunan (2014) emphasized that teacher's understanding of the technology was a critical factor to achieve the desired outcome. Similarly, without proper understanding how interactive screen should be used, the interactive screen could reduce the amount of students' dialogue or amount of group work (Holmes, 2009).

Notably, knowledge about the technology is not required separately, but in the relation with content knowledge and pedagogical knowledge, in accordance with Technological Pedagogical Content Knowledge (TPCK), as this framework was considered essential for teachers to promote effective teaching with technology (de Silva, 2016). In TPCK, content knowledge refers to knowledge about the actual subject matter; pedagogical knowledge refers to understanding of processes and practices or methods of teaching; technological knowledge refers to knowledge about standard and advanced technologies along with the skills to operate the technology (Mishra and Koehler, 2006). TPCK framework emphasizes the connections, interactions, affordances and constraints between and among content, pedagogy, and

technology as central to good teaching (see figure 7). They explained that the relationship between content, pedagogy and technology was complex, hence, it was inappropriate to isolate one aspect from the others. TPCK implies that knowing how to use technology alone does not mean knowing how to teach with it (Mishra and Koehler, 2016). Specifically, the interactive screen would be least effective when teachers do not have a new pedagogy approach (Armstrong et al., 2005). Therefore, knowledges about the technology, in relation with content and pedagogy should be provided to help teachers know how, when and why to use the technology in classroom, so that technology could be used in accordance with the purpose of utilization (Burke, 2005), and thus, decide the effectiveness of technology in classroom (Johnson, Jacovina, Russell, and Soto, 2016).

Based on this, it is hypothesized that teachers' lack of technological-pedagogical-content knowledge would be a factor that hinders the effectiveness of Classroom of the Future.

Figure 7



Technological Pedagogical Content Knowledge (Mishra and Koehler, 2006)

Based on the theoretical framework. The following hypotheses are established for the research questions:

Research question 1: In what ways does the Classroom of the Future facilitate the implementation of IALA in engineering classes?

Hypothesis 1: Space in the Classroom of the Future allows free interaction between teachers and students.

Hypothesis 2: Furniture in the Classroom of the Future enables peer interaction.

Hypothesis 3: Interactive screen in the Classroom of the Future enables easy information sharing.

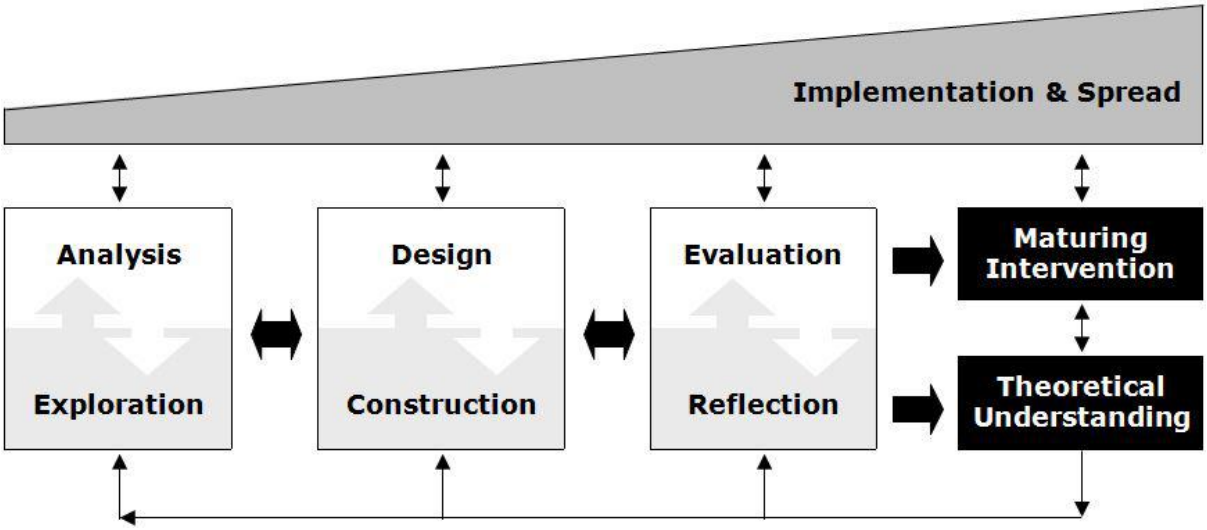
Research question 2: What hinders the effectiveness of the Classroom of the Future in supporting the implementation of IALA in engineering classes?

Hypothesis 4: Teachers' lack of technological-pedagogical-content knowledge would hinder the effectiveness of the Classroom of the Future.

4. Evaluation framework

McKenney and Reeves (2012) proposed a process of educational design research, which includes three core phases: Analysis, Design, Evaluation. This process is iterative because the result of one phase can be used to feed into the others. More specifically, with the result from the 'Analysis' phase, the intervention or project is designed and then constructed. The product of the 'Design' phase gives context and input for 'Evaluation'. In return, the conclusion and recommendation of the 'Evaluation' phase can be used as input to improve the design and mature the intervention. The whole process is visually illustrated as the Generic model for conducting design research in education (shown in figure 8). Accordingly, this research is at phase three: Evaluation. The outcome of this research will fuel the redesign of the Classroom of the Future so that the project can be improved.

Figure 8



Generic model for conducting design research in education (McKenney and Reeves, 2012)

This research is the evaluation of a project, which serves as a testing ground before the idea and design can be widely applied throughout the campus. Thus, according to McKenney

and Reeves (2012), within the 'Evaluation' phase, this research is of 'Beta' testing, which tests the project's use in context. In 'Beta' testing, the evaluation focuses on local viability and institutionalization. While 'local viability' investigates how the project survives in the immediate context, how the project performs and the factors that influence its implementation, 'institutionalization' focuses on how the project becomes absorbed within the broader educational context. An overview of the three testing phases of the 'Evaluation' can be found in table 1. The main questions to ask during 'Beta' testing (McKenney and Reeves, 2012) are:

- How relevant and usable do practitioners perceive and experience the project?
- What intended and unintended processes are engendered by the project?
- What makes embodiments of certain mechanisms more resilient than others?

Table 1

Phase and Focus of Evaluation

Phase	Focus
Alpha testing	Soundness
Functionality of initial intervention prototypes are tested	Feasibility
Beta testing	Local viability
Functionality of the project and its interaction in context are studied	Institutionalization
Gamma testing	Effectiveness
Final or highly stable version of the project is tested	Impact

From this approach, this research comes close to the evaluation by adopting the Pedagogy – Space – Technology framework from Radcliffe (2009). The reason this framework is chosen is that it focuses on the interaction of the three elements: pedagogy, learning space and ICT, which are also the focus of this research. The framework is a series of generated questions instead of a prescriptive model so that it can be easily adapted to different stakeholders and contexts. The framework allows additional questions to be added based on the specific purpose of the project. Radcliffe's framework consists of two evaluation stages namely Conception/Design and Implementation/Operation. In the scope of this research, the evaluation framework for Implementation/Operation Stage is adopted and shown in table 2. Beside Radcliffe's framework, TPCK framework was also used to guide the researcher's observation and the interviews with the teachers. For instance, how teachers perceive IALA, what teachers know about the interactive screens, and how teachers perceive the usefulness of the interactive screen in IALA. These frameworks were used as the basis to design instruments

to collect data instead of the validated instruments, in order to suit the specific design and function of features of the Classroom of the Future and the purpose of this thesis.

Table 2

Pedagogy – Space – Technology framework on Implementation and Operation Stage (Radcliffe, 2009)

Focus	Implementation and Operation
Overall	Is the facility considered to be a success? Why? What is the evidence? Does this relate to the original motivation or intent? What lessons were learned for the future?
Pedagogy	What type(s) of learning and teaching took place?
Space	Which aspects of the space design and equipment worked, and which did not? What were the unexpected impacts (positive and negative) of the space on teaching and learning
Furniture	Which aspects of the furniture worked, and which did not? What were the unexpected impacts (positive and negative) of the space on teaching and learning
ICT	What technologies were effective at enhancing learning and teaching? What were the unexpected (unintended) impacts (positive and negative) of the technology on learning and teaching?

5. Methods

5.1. Cross-case research design

This study employs the cross-case study method. According to Rowley (2002), case study research has some typical characteristics. First, it offers insights that might not be achieved with other approaches. Second, the case study is a useful tool for the exploratory stage of a research project, to answer 'how' questions. Third, case study researcher has much less control over the variables. Moreover, the cross-case methodology is appropriate for community and system change research and evaluation (Lee and Chavis, 2012), particularly in education (Stake, 2010). Multiple cases also provide greater confidence in findings of the overall study

(Yin, 2014). Hence, cross-case study method is consistent with the goals of this research and was used to guide the design of this research.

In the cross-case study, methodological and data source triangulations allow the research to have constructive validity and reliability (Lee and Chavis, 2012). Therefore, each sub-research question in this study was answered by multiple data sources, particularly from the information letter from the Classroom of the Future, interviews with teachers, surveys with students and observation from the researcher, and thus, produced both qualitative and quantitative data. A full measurement framework was created to clarify the different methods and data sources necessary for triangulation. The measurement framework can be found in table 3.

Table 3

Measurement framework

Component	Data collection	Indicator and measure
1. How Classroom of the Future facilitates IALA	• Students' survey • Interviews with teachers • Researcher's observation	• Space is suitable for both individual and group learning • Space eliminates physical barrier between teacher and students • Furniture can be shifted easily • Furniture can be used to form round-table • The interactive screen can be used to search for information • The interactive screen can be used to share information and product • Furniture and the interactive screen can be used without major difficulties
2. What hinders the use of Classroom of the Future	• Information letter • Researcher's observation • Interviews with teachers	• Information on how the interactive screen can benefit the implementation of IALA • Information on how the interactive screen can be used in IALA

• Students' survey	• Difficulties in using the Classroom of the Future

5.2. Participants

The three teachers are from engineering programs at the University of Twente. They registered to use the Classroom of the Future in the first quartile of the academic year 2018-2019 to deliver the lesson to undergraduate classes. They are fluent in English, which is the instructional language, and can use the tools and software supporting teaching and learning process, such as laptops, PowerPoint, web browsers. The students are from the corresponding undergraduate engineering programs at the University of Twente. The total number of students as participants was 200. The students have basic computer skills and are fluent in English. No distinctions were made in the gender or ethnicity of the participants.

5.3. Instruments

Survey

The survey was aimed to collect students' opinion regarding features of the Classroom of the Future. The survey contained 17 items. The first three questions gathered crucial background characteristics of students, including educational level, gender, and age. In the next nine questions, students were asked to give their opinions in Likert scale, ranging from totally disagree (1) to totally agree (5), on the usability and effectiveness of space, furniture and interactive screen of the Classroom of the Future in supporting the implementation of IALA. More specifically, item four asked for students' overall review about the Classroom of the Future. Item five asked for asked for students' review about the space in the Classroom of the Future. Items six and seven asked for students' review about features of the furniture in the Classroom of the Future. Items eight and nine asked for students' review about features of the interactive screen in the Classroom of the Future. Items ten and eleven asked for students' review about the usability of the furniture and interactive screen. The last six open questions asked students to elaborate for their opinions, suggest the benefits which have not been mentioned, listed the difficulties and give suggestions on additional support so that space, furniture and interactive screen can be more effective. The online survey can be found in appendix B.

Semi-structured interview framework

The semi-structured interview is an ideal tool to capture the meaning behind action and experience while maintaining the focus in a specific topic (Rabionet, 2011), and hence, was

used to record teachers' opinions. The semi-structured interview was divided into six sections, using Radcliffe's (2009) framework. The 'Pedagogy' section was about the teachers' initial purpose when using the Classroom of the Future and whether they achieved their goal. The 'Space' and 'ICT' sections covered teachers' experience in using the space and ICT in the Classroom of the Future, the perceived benefits, difficulties when using them and the knowledge and belief towards their function. The 'Additional factors' part of the interview was about the support, guidance and information teachers receive before and during class on how to use Classroom of the Future; and teachers' viewpoint toward active learning method. The 'Overall' section asked for teachers' comparison between the Classroom of the Future and regular classrooms. Finally, in the 'Suggestion' section, teachers were asked for their recommendation on further support and guidance, the learning activities which might (not) be suitable with Classroom of the Future and other facilities which might benefit the implementation of IALA. Besides the planned questions, additional questions were asked to help clarify teachers' ideas. The interview framework can be found in appendix C.

Class observation checklist

Non-participant observations were conducted to create the description of each class and was added to the triangulation of data. Moreover, observation allows the researcher to see what teachers and students do, rather than what they say they do (Morgan, Pullon, Macdonald, McKinlay, and Gray, 2017). Therefore, observation allowed researcher to see what the participants did not realize about their behaviours in class and the situation they were in. The class observation checklist was created based on Radcliffe's (2009) framework. Notes were taken as well. There were five main parts in the checklist, namely 'Pedagogy', 'Space', 'Furniture', 'ICT' and 'Overall'. In the 'Pedagogy', the structure of the lesson, detail of the learning activities was described. In the 'Space', 'Furniture' and 'ICT', whether and how teacher and students used space, furniture and ICT, the additional support provided or needed were recorded. The 'Overall' explored the reaction, attitudes of the students during class and the researcher's impression of the whole class. The class observation checklist can be found in appendix D.

5.4. Procedure

Before starting the project, the ethics committee of the University of Twente was asked for approval for this study. The Dream Team, who assisted teachers and students working in DesignLab and the Classroom of the Future, were requested to share the information about the Classroom of the Future which teachers received. Teachers as respondents were asked for

permission before class observations and semi-structured interviews were conducted. All respondents were asked for consent and informed of the purpose of the study.

Three weeks prior to the start of the academic year 2018-2019, eight teachers who registered to use Classroom of the Future in the first quartile of the academic year 2018-2019, were invited to participate in the research. Due to busy schedule, most of the teachers did not reply to the first invitation. Reminders were sent to the teachers one week after the first letter. Eventually, three teachers replied with the acceptance to participate in this research. One week prior to each class, a reminder of the class observation was sent to the teacher.

The total time of the study was 480 minutes. With the permission from three teachers as respondents, the researcher observed one class of each teacher. The first class lasted for 90 minutes, excluding break time, from 13:45 to 15:30. The second class lasted for 165 minutes, excluding break time, from 8:45 to 12:00. The third class lasted for 165 minutes, excluding break time, from 13:45 to 17:30.

After the class, all students of classes one and two were asked to fill in the online survey. Because classes two and three shared the same students, hence, the students were asked to fill in the survey once in class two. To help students focus on only one class, the announcement of the survey was made right after the class two, and the link to the survey was provided only in the folder of class two on Canvas. The survey took five to seven minutes to complete. The online survey was created using the Qualtrics online survey tools provided by the University of Twente and was distributed to students through Canvas, the official learning management system of the University of Twente. Respondents' anonymity was guaranteed and mentioned as part of the instruction given prior to the completion of the survey. After one week, 70 completed surveys were returned. The response rate was 35%. Data were inserted in SPSS for data analysis, which was carried out by the researcher over a period of seven working days.

The teachers were contacted to arrange the appointment for the interview after their class in the Classroom of the Future. There were three interviews in total. Each interview lasted for approximately 20 minutes. The interview with the teacher of the first class was conducted in the teacher's office at the University of Twente. The interviews with two other teachers were conducted in the Classroom of the Future. The interviews were conducted in a formal style. There were one interviewer and one interviewee present in each interview. The interviews were voice-recorded.

5.5. Data analysis

5.5.1. Quantitative data

Background characteristics. Descriptive statistics were used to describe basic features and simple summary about data on gender, age and educational level in each case.

Students' ranking on the usability and effectiveness of space, furniture and ICT. First, mean of each item was found. Second, the score means of 'furniture' and 'interactive screen' were computed. Score mean of 'furniture' was equivalent to the mean of items six and seven. Score mean of 'Interactive screen' was equivalent to the mean of items eight and nine. Then, the feature score means of 'overall', 'space', 'furniture', 'interactive screen', 'furniture usability', and 'interactive screen usability' were computed. If the mean or feature score mean is lower than 2.55, the students disagreed with the statement. If the mean or feature score mean is between 2.55 and 3.55, the students had neutral idea about the statement. If the mean or feature score mean is higher than 3.55, the students agreed with the statement. The means, along with students' elaboration, teacher's interview and researcher's observation showed if and how each feature of the Classroom of the Future was beneficial and used in each case.

Cross-case comparison. The Wilcoxon Rank Sum test was used to compare review on the score of 'overall', 'space', 'furniture', 'interactive screen', 'furniture usability', and 'interactive screen usability' between case 1 and 2. Wilcoxon Rank Sum test was used because the scores in Likert-typed items were not continuous, but were integer values, and the distribution of the two cases were not equal. Based on the result, it will be concluded whether the difference between cases were significant.

5.5.2. Qualitative data

Information letter. The information letter was analysed using Burke's (2005) criteria. More particularly, the letter was checked whether the information about why, when and how to use the interactive screen and main LED screen was presented to the teachers.

Semi-structured interview. Recorded interviews were transcribed by the researcher. The qualitative data was coded following Gordon's (1998) basic steps in coding. First, the coding scheme was created. The main categories within the coding scheme included pedagogy, space, furniture, ICT, suggestion and off topic. Second, category symbols were assigned. Third, information from the interviews was classified according to the coding scheme. Transcribed interviews were consulted for understanding or gaining insights in the results when needed.

Students' answers for open questions. The data from open questions of each case was gathered in the same document. The answers of students for open questions targeted specific questions about features of Classroom of the Future, thus, the categorical analysis was not necessary. Instead, the data was directly interpreted and then used to clarify the majority of students' opinions on each feature of the Classroom of the Future.

Class observations. The data was first used to describe the case and later directly interpreted and referenced in the final result of each case and of the overall study.

6. Results

After the data was analyzed, the results of the information letter and each case were demonstrated. The comparison of the three cases was presented at the end of this section.

6.1. The information letter analysis

The information letter was the only material the teachers received before and during their classes at the Classroom of the Future. The analysis result showed that the only information that matched Burke's (2005) criteria was how to use the main LED screen. More particularly, it was stated in the introduction letter that 'You can bring your own laptop and plug it to the screen'. Other necessary information regarding when, why and how to use the interactive screens, as well as when and why to use the main LED screen was absent. The summary of the analysis can be found in table 4.

Table 4

Introduction letter analysis result

	When to use	Why to use	How to use
Interactive screen	✗	✗	✗
Main LED screen	✗	✗	✓

✓ = present; ✗ = absent

6.2. Case 1

There were three teachers, one main and two guests, in the class. The number of students registering for the class was 110. On the observation day, there were around 90 students. With two people fitting in one table, forty tables were not enough for all the students. Therefore, around ten students sat without a table (see figure 9). The main LED screen was at the front, while there were sixteen interactive screens placed along the two walls of the room (see figure 10). Five screens were on (see figure 11). The class started at 13.45 with a 15-minute introduction of the guest teachers and the lesson format. In the next 45 minutes, the guest teachers explained how the students could use a specific software step by step to conduct their group assignment. During this time, the students looked at the slides on the interactive

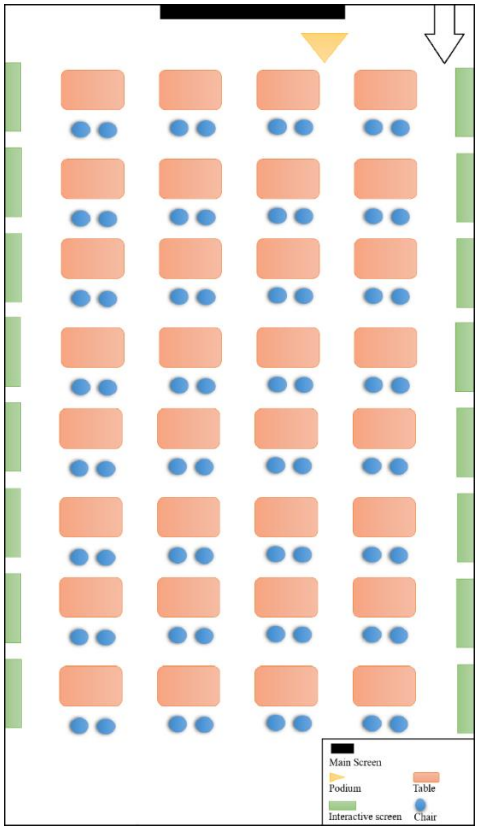
screens, which were mirrored from the main LED screen at the front. After the 15-minute break, the class resumed at 15.00. The main teacher gave a short instruction on what students had to do next. No instruction was given on how the interactive screen could be used. After that, students gathered around the table in groups of five to six people to discuss their project. The students did not share their information with other groups or share the result with teachers. One group used the whiteboard to make notes. However, there was only one whiteboard in the class, hence, the other groups used their laptops and notebooks instead to view information and make note. During the discussion, the main teacher and guest teachers walked around the class to give additional help when students were in need. The main teacher reminded the students of the next step in the process which groups had to follow before wrapping up the class at 15.30.

To sum up, according to the observation, there was one IALA, namely intra-group discussion, in this class. Space was spacious enough for teachers to approach students and for the students to discuss without disturbing other groups with noise. The furniture could be shifted, which was useful for students to form groups. On the other hands, the interactive screens were used only in the lecture and not during the intra-group discussion. Although the interactive screens assisted the students to keep track with the presentation, they were less helpful for students who sat at the two rows in the middle than those who sat at the two rows outside because of the distance.

Figure 9

There were not enoguh tables for all the students

Figure 10



The setup of the Classroom of the Future at the beginning of the class

Figure 11

Five interactive screens were on and the remaining interactive screens were off.

Students' survey.

There were 30 respondents (response rate 33.3%), in which 18 were male (60%) and 12 were female (40%), aged 19 to 22 years old (M = 20.4, SD = 0.77). Detailed results from the quantitative data analysis of case 1 are presented in table 5.

Table 5

Result of students' opinions in case 1 (N = 30)

Feature	Item	*Score Mean*	*SD*	***Feature Score Mean***
Overall	It is more favourable to implement IALA in Classroom of the Future than regular classrooms	3.63	1.129	**3.63**
Space allows interaction	The teacher was able to approach comfortably to the students	3.57	1.040	**3.57**
Furniture enables peer interaction	The flexible furniture helped me to form group quickly	3.77	1.305	**3.60**
	The flexible furniture helped me to sit and discuss with group members easily	3.43	1.569	
Interactive screen allows information sharing	The interactive screens were convenient for sharing information	2.47	1.943	**2.65**
	The interactive screens were convenient for sharing presentation	2.83	1.913	
Furniture usability	I could use the flexible furniture easily	3.93	.980	**3.93**
Interactive screen usability	I could use the interactive screens easily	2.57	1.832	**2.57**

Agree Neutral Disagree

Overall. The result from the survey showed students agreed that in general, Classroom of the Future was more favourable to implement active learning activities than the regular classrooms (M = 3.63, SD = 1.129). Students suggested that the Classroom of the Future should be suitable for 'brainstorm' or 'groupwork'.

Space. The students agreed that the space allows free interaction between teachers and students (M = 3.57, SD = 1.040). Students described the space as 'spacious' and 'open'. However, with the current number of students, the space 'was completely full'. Besides, there were some minor concerns with the space set up, particularly the presence of socket poles and interactive screens made the space setup 'messy' or 'distracting'.

Furniture. The students agreed that the furniture was favourable for IALA (M = 3.60). Students also agreed that the furniture was easy to use (M = 3.93, SD = 0.980). Nevertheless, most of the drawbacks of the furniture related to the lack of tables for 120 students when the students sat individually facing the main LED screen for the lecture. Furthermore, due to the large number of students, 'Moving tables and other stuff was hard'.

Interactive screen. The students had neutral idea about whether interactive screen enabled easy information sharing (M = 2.65). This was because students acknowledged that although the screen 'helped the teacher reaching the whole class' by 'allowing easy screen sharing', they 'were not properly used in IALA'. Notably, students required 'more white boards' for sharing plan, notes, ideas among group members. Concerning the ease of use the interactive screens, students also had neutral idea (M = 2.57, SD = 1.832). Some difficulties regarding the use of interactive screen included 'they reflected the sunlight' and 'could not be seen from the middle rows'. Additional feedback regarding ICT was that 'the main screen cannot be seen from certain seats'.

Teacher's interview.

Analysis of interview with the teacher in case 1 showed that 86.6% of the utterances were on task. Example of off-topic utterance includes 'I had some lecture at IDEATE but it did not work at all'. The interview was explored for further insights into the results, with the main focus on on-topic utterances. In general, the teacher in case 1 was satisfied with the experience in the Classroom of the Future. He registered to use Classroom of the Future because it is 'big enough for 110 students' and 'allows students to work in group'. He considered the experience at Classroom of the Future 'a nice opportunity'.

Regarding the space, the teacher appreciated the room's open space in supporting the implementation of IALA, as 'it's wide enough to walk around to help students' and enables him to 'easily split the room to smaller sections where students can discuss' and prevents 'one group being disturbed by other groups, in terms of too much sound'. Furthermore, the quality of the sound system was good, so the teachers could reach all the students during the lecture. The teacher did not indicate any difficulty when using the space.

In terms of ICT, the teacher acknowledged the advantage of interactive screen in ‘allowing students to follow the presentation’. However, in intra-group discussion, he thought the students ‘used the laptop as the group is not so big, so looking at one laptop screen is also visible’. Besides, the teacher considered the ‘inability to use the pointer’ and ‘a cross on the slides’ as some disadvantages in using the main LED screen.

Regarding the understanding about the technology in the Classroom of the Future, the teacher confirmed that the information letter was the only material he received from DesignLab. The teacher said that he was shown in the letter ‘that the setting is flexible, there are big screens to show students presentation but also to use as separation parts’. Information about function, special features or how to use the interactive screen was not provided by any other sources. Therefore, when asked why he did not use the interactive screen, the teacher said he was ‘not sure the interactive screens are necessary’. Apart from that, the teacher praised the technical support as ‘well organised’ because ‘there’s always help available if there are any problems’. Besides, although the teacher understood the benefits of active learning, what prevented him from taking more advantage of this method was the lack of experience. Therefore, he suggested that ‘it would be nice to have support and suggestions of the examples on how you can organize it, how you can approach it, how you can implement it, how to use the interactive screens and facilities. So, you can choose the suitable method for your lecture’, and the ‘suggestion should be in a video’.

6.3. Case 2

The number of students registering for the class was 120. On the day of observation, there were approximately 100 students. With two people fitting in one table, forty tables were not enough for all the students. Therefore, around twenty students sat between the tables or at one side of the table. The main LED screen was at the front. All sixteen interactive screens along the two sides of the room (see figure 6) were off. The class started at 8.45 with the teacher’s preparation with the computer and main LED screen. However, there was a problem with the main LED screen, hence the teacher started to write on the whiteboard with a marker. After the preparation, the teacher reviewed the previous lesson and gave the students a problem to solve. No instruction on how the interactive screens could be used. At 9.10, students sat at their position to work on their own or discuss with the person next to them. They mainly used notebooks to calculate. After ten minutes, the teacher gave the answer on the whiteboard. At 9.30, the teacher started to deliver the next part of the lesson. He used the main LED screen to show the slides and students looked at the slides from their own laptops. Most of the time, the

teacher used the whiteboard, which could not be seen from the back. That was why some students had to stand up. It could be the reason why some students did not focus on the lesson or left the class after the break. The teacher asked several problem-solving questions during the lecture. The students raised their hands to answer but it was difficult to hear from the back. The lesson went on until 11.30. After that, the students were free to leave or do the assignment. The students could go to the teacher's desk to ask their questions.

To sum up, according to the observation, there were several IALAs, namely Mathematics problem-solving, in this class. However, students mainly worked individually. They were also not required to share their answers; hence the special features of space, furniture and interactive screens were not taken advantage of. The condition of the ICT was not favourable for the lecture, as there were technical problems with all the screens. The use of the whiteboard to replace the main LED screen was absolutely not suitable with such a long classroom because students at the back could not see anything written by the marker on the board.

Students' survey.

There were 39 respondents (response rate 39%), in which 20 were male (51.3%) and 19 were female (48.7%), aged 19 to 24 years old (M = 20.4, SD = 0.97). Detailed result from the quantitative data analysis of case 2 is presented in table 6.

Table 6

Result of students' opinions in case 2 (N = 39)

Feature	Item	*Score Mean*	*SD*	***Feature Score Mean***
Overall	It is more favourable to implement IALA in Classroom of the Future than regular classrooms	2.56	1.392	**2.56**
Space allows interaction	The teacher was able to approach comfortably to the students	3.33	1.383	**3.33**
Furniture enables peer interaction	The flexible furniture helped me to form group quickly	2.46	1.232	**2.67**
	The flexible furniture helped me to sit and discuss with group members easily	2.87	1.151	

Interactive screen allows information sharing	The interactive screens were convenient for sharing information	1.28	1.075	**1.55**
	The interactive screens were convenient for sharing presentation	1.82	1.355	
Furniture usability	I could use the flexible furniture easily	2.92	1.036	**2.92**
Interactive screen usability	I could use the interactive screens easily	1.44	1.165	**1.44**

Agree Neutral Disagree

Overall. The result from the survey showed that students had neutral idea about whether Classroom of the Future was more favourable to implement IALA than regular classrooms (*M* = 2.56, *SD* = 1.392). Students explained that they had 'negative experience with a normal lecture being conducted here', although some of them could see that the 'facilities are favourable for active learning', which made Classroom of the Future 'has some potential'. One student emphasized 'teachers do have to know what the possibilities of the room are and how to implement these in their lectures'. Meanwhile, some students even thought 'a regular classroom is more favourable'. One student summarised 'the room has more facilities to implement active learning activities, but it is less favourable for normal lectures than a regular classroom', therefore, 'this classroom could be favourable compared to regular classrooms if suitable learning methods would be used'. Activities which were suggested to be suitable with Classroom of the Future included 'tutorial', 'presentation', 'brainstorm', 'workshop', 'project work', 'programming'.

Space. The students had neutral idea about whether the space allowed free interaction between teachers and students (*M* = 3.33, *SD* = 1.383). Students described the space as 'spacious' and 'available for both group work and lecture'. However, there was a considerable amount of comments about the 'distracting setup', and that the room was 'too crowded' for 100 students.

Furniture. The students also had neutral idea about whether the furniture could be shifted easily to enable peer interaction (*M* = 2.67), and whether the furniture was easy to use (*M* = 2.92, *SD* = 1.036). It could be seen from the observation that there was no group activity for the students, hence, they did not move the table to form groups and did not have a specific

opinion about the special features of the furniture. However, if they had done that, ‘the furniture could not be moved because the classroom was too full’. Also, there were eight times which students said ‘there was not enough table’ for 100 students.

Interactive screen. The students strongly disagreed that the interactive screen enables information sharing (M = 1.55). Students explained ‘the interactive screens aren't used to their full possibility’ because ‘they didn’t ask us to use the interactive screens’ and ‘nobody explained what we can do with the screens’, hence ‘most things have to be done on our own laptops’. Finally, they completely disagreed that they could use the interactive screen easily (M = 1.44, SD = 1.165). Students explained that they ‘could not get the interactive screens to work’, ‘they are too complicated’, and ‘people from DesignLab did not even know how to use them’.

Many comments were given on how the presentation was difficult to see from the main LED screen because the screen ‘is too small’, ‘has a big cross which cut the important texts’, and ‘not located at easily visible places’. Students also strongly criticized the use of the whiteboard, because it ‘could not be seen from the back’ and ‘not sufficient for mathematics-oriented subjects’. Thus, they suggested ‘using interactive whiteboard’.

Teacher’s interview

Analysis of the interview with the teacher in case 2 showed that 86.5% of the utterances were on-topic. Example of off-topic utterance includes ‘I can see from the exam that they know how to remember things and they can apply it and they can solve problem’. The interview was explored for further insights into the results, with the main focus on on-topic utterances. In general, the teacher in case 2 was not pleased with his experience in the Classroom of the Future. He considered it as his ‘least favourite’, because ‘this room is very much not suitable for Mathematics class’ and ‘it doesn’t really suit my need or my teaching method’. The reason he chose to use Classroom of the Future was ‘this was the only available classroom that is large enough to hold all the students’.

The teacher did not particularly like or dislike the space in the Classroom of the Future. It could be explained by the fact that the features of the space were not used, as students did not have to move around to form groups in this class, while the teacher also ‘glued to the podium’, because he ‘has to work with the tablet, while the screens did not work, he cannot move away from it’. Another concern he had regarding space was ‘the room is level so students at the back cannot see the board’. On the other hand, what he found helpful in the Classroom of the Future was that the small tables were favourable for individual problem-solving tasks, and the tables enable students to ‘easily work together, better than when they sit on long benches’.

In respect of the ICT, the teacher thought the interactive screens were not handy to use as he reported the technical issues 'were pretty terrible' because too many technical problems occurred with the main LED screen, the interactive screens, and the sound system in this class, which caused lesson disruption, and made the teacher to use the white-board to give the information to students.

Regarding the understanding about the technology in the Classroom of the Future, the teacher said that before the class, he received the introduction letter by email. There was also a paper folder on the teacher's desk. However, the paper folder was the introduction of DesignLab, with information about different rooms and spaces there. To sum up, the teacher received the information about how to get the screens to work and how to fix them, yet, he 'did not get any specific instruction'. Therefore, when asked why he did not use the interactive screen, the teacher said, with the IALA as solving Mathematics problem in his class, he thought 'the facilities are not necessary'. The teacher suggested that besides the manual, he 'would like to have a half-hour instruction before the start of the module'. In addition, when he had technical problems, 'they could not help me with that' leading to his negative experience with Classroom of the Future. Besides, regarding the IALA, the teacher 'did try to give the students small problems to work on' and had some ideas on how it could be implemented, for example, by 'having somebody to give their solution' on the interactive screens, 'short quizzes', 'discussion'. Yet, there were not many IALA in this class because of two main reasons. First of all, the teacher believed that 'the current method works', and his course 'is simply Maths. So, interactive activity wouldn't have to be with them'. The second reason was he doubted it would work for 120 students, thus, he supposed 'smaller groups would be easier to have some of them do it'.

6.4. Case 3

This class had the same students from the second case, hence, students' opinions were not collected again. On the observation day, there were around 110 students coming to class, so, Classroom of the Future was crowded. Many students sat at the side of the tables. Fifteen students placed their chairs on the pathway. The main LED screen was at the front. All sixteen interactive screens along the two sides of the room (see figure 7) were off. At 13.45, the teacher started to give the lecture using the main LED screen. Students looked at the slides from their own laptops. At 14.20, the students had ten minutes to work on a short problem-solving task individually or in small groups of two or three. Then, the teacher used the whiteboard to explain the answer and kept delivering the lesson. During the first break from 14.45 to 15.00, Dream

Team came to turn on the interactive screens. When the class resumed, the teacher used the webcam on his laptop to show the students a small detail of the machine. The students focused on the interactive screen. After the second break from 15.40 to 16.00, the students started to work with the assignment in groups of four to six (see figure 2). Each group had a model machine placed at the centre of the table. The students in one group sat around the tables with their laptops in front of them. The teacher moved around to give help when the students were in need. The group work went on until the class ended at 17.30.

To sum up, according to the observation, there was one IALA, namely group programming, in this class. Space enabled teachers to interact comfortably with student groups while the furniture helped students to form groups quickly. However, there were tables of different sizes in the Classroom of the Future (see figure 12). When the students put two tables of small width together, the space between the students in one group was appropriate for discussion (see figure 13). Meanwhile, when the two tables of big width were put together, the space between group members was too big, which forced the students to lean forward and stand to listen to each other (see figure 14). Moreover, the students used their individual laptops although the laptops prevented them to see the model system placed at the middle of the group. Some students had to lean forward or lean on one side to see the model. The laptops were also not favourable for sharing information when three to four students had to stand up and look at one small screen (see figure 15). These two problems could have been solved if the students had used the interactive screens. Unfortunately, the interactive screens were used only in the lecture and not during the IALA.

Figure 12

Two tables of different length and width

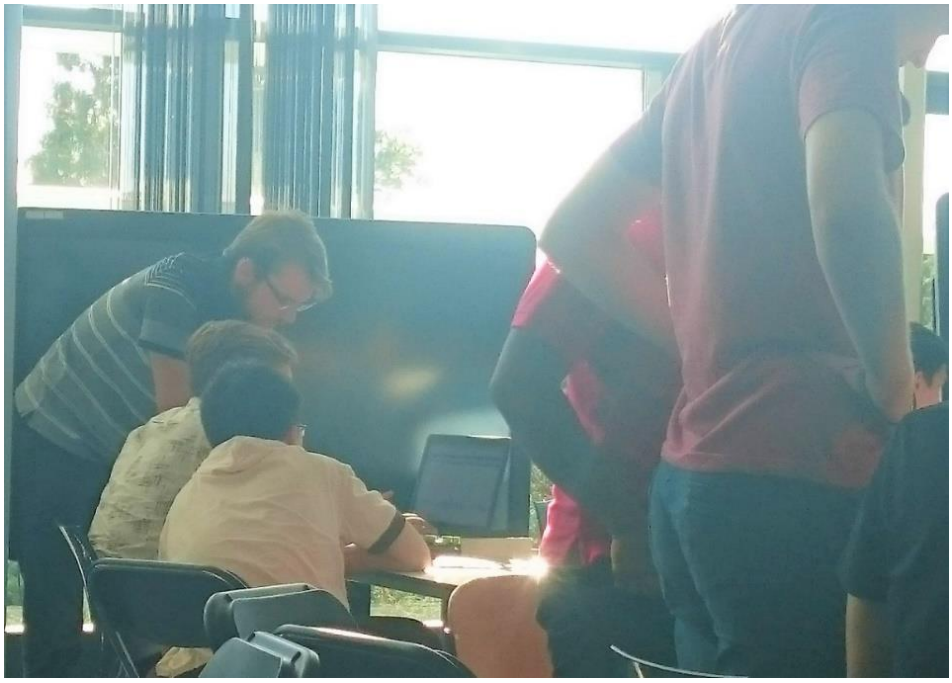
Figure 13

Two tables of smaller width made an appropriate group space

Figure 14

Two tables of larger width made wide gap, which forced the students stand on one side of the table to discuss.

Figure 15



Many students had to stand to look at the small laptop screen while the big interactive screen behind them was not used.

Teacher's interview

Analysis of interview with the teacher in case 3 showed that 98.0% of the utterances were on-topic. Example of off-topic utterance includes 'There are enough power outlets'. The interview was explored for further insights into the results, with the main focus on on-topic utterances.

In general, the teacher in case 3 had a neutral opinion about the Classroom of the Future. He considered it 'similar to other classrooms' because 'there's no reason it's harder or less hard here than in the other rooms'. The reason he registered to use Classroom of the Future was 'there were no other rooms that could fit this number of students'. Space in the Classroom of the Future was praised as the teacher 'had enough space to approach and interact with students'. However, the teacher recognised that 'there seems to be not enough table'. In contrast, the ICT brought not much value to the teacher. Particularly, according to his opinion, the main screen 'is made out of 4 screens. Often large important part is at the boundary between the two screens and it's hard to see'.

Regarding the understanding about the technology in Classroom of the Future, the teacher confirmed that the introduction letter was the only material he received from DesignLab. Therefore, when asked why he did not use the interactive screens, the teacher said he did not know what to do with the interactive screens and wondered 'what could they do with

it? Is there anything they could do with this touch screen that they cannot do on paper? Can they take their stuff home? I don't know about that'. Concerning IALA, the teacher was not interested in incorporating activities in his class 'because I just want to do a normal lecture'. He clarified that he has 'already given this lecture last year and it worked well so, there's no need to change it, or improve it or do other things'. Besides, IALA 'would have taken too much time', while he 'couldn't think of any way how this could improve the lesson'. Last but not least, if he could be shown how to use features in the Classroom of the Future, he preferred having the instruction incorporated in a short video.

6.5. Cross-case comparison

The three cases in this research were all undergraduate engineering classes, with similar number of students. In all three cases, the Classroom of the Future was chosen by the teachers only due to the number of seats available, instead of the special features it provided. The three classes occurred in a similar format, with lecture in the first half or two third of the class, followed by IALA at the end of the class. Each case had a different IALA, which was intra-group discussion in case 1, individual Mathematics problem-solving in case 2, and group programming in case 3. The activities occurred during IALA of each case, which could be supported by special features of the Classroom of the Future, can be found in table 7.

Table 7.

Activities during IALA of three cases

	Teacher – student interaction	Intra-group interaction	Inter group interaction	Group form	Search information	Share information
Case 1	✓	✓	×	✓	✓	✓
Case 2	✓	×	×	×	×	×
Case 3	✓	✓	×	✓	✓	✓

✓ = present; × = absent

By comparing data from three cases, the review regarding each feature was described below. The Wilcoxon Rank Sum Test result can be found in table 8.

Overall. The Classroom of the Future was agreed to be more favourable than regular classrooms when conducting IALA in case 1. Meanwhile, the same issue was neither agreed or disagreed in case 2. The Wilcoxon rank sum test result showed the difference between case 1 and case 2 was significant ($p \leq .0001$).

Space. The space was agreed to be favourable for interaction in case 1. Meanwhile, the same issue was neither agreed or disagreed in case 2. Yet, the difference in students' review between case 1 and 2 was found not significant ($p > .05$). The students of all classes also reported the same problems that the setup of the space was distracting because there were too many elements, such as socket poles and screens, in the space. Moreover, there were not enough tables and the room was too crowded for 90 students or more.

Furniture. The benefit of furniture in IALA was inconsistent between cases. While the furniture was agreed to facilitate interaction in case 1, the same issue was neither agreed or disagreed in case 2. The difference was found significant ($p \leq .0001$). Also, the furniture was agreed to be easy to use, which was significantly different ($p \leq .001$) compared to the neutral idea in case 2. Yet, all teachers and students reported the lack of tables for 100 students

Interactive screen. The interactive screen in appreciated in case 1 and 3 for being able to mirror the presentation from the main screen during the lecture. Nonetheless, interactive screens were not used in intra-group discussion in case 1 or group programming in case 3. Therefore, the interactive screen was neither agreed or disagreed to be helpful in sharing information. In contrast, the interactive screens were not used in lecture as well as in the Mathematics problem-solving task in case 2. Therefore, the interactive screen was disagreed to be favorable for IALA. The difference between case 1 and 2 was significant ($p \leq .0001$). Furthermore, students in case 1 had neutral opinion about whether the interactive screens were easy to use, while the students in case 2 disagreed because they experienced technical problems when they tried to make the interactive screens work in lecture. The difference was significant ($p \leq .0001$). Opinions towards the difficulties in using the interactive screen were diverse. In case 1, the students sitting in the middle row could not see the interactive screens, while the students in case 2 found the interactive screens too complicated to use.

Regarding the main LED screen, in three cases, it was reported with the same problem of the cross on the screen, which made it difficult for students to see the whole content of the slides. Furthermore, the teacher is case 1 could not use the pointer on the LED screen. While students thought the main screen should be at higher position for students at the back of the room to see properly.

TPCK. All teachers received an introduction of the facilities of Classroom of the Future through email. Yet, there was no instruction on how to use the interactive screens in the Classroom of the Future. As a results, the teachers said they did not use the interactive screens because they did not know how the interactive screens could benefit their teaching and the student's learning. All of the teachers thought the interactive screens were not necessary during

IALA, although from observation, it was found that many activities could have been supported better with the help from interactive screens. For example, when students in case 1 and 3 had difficulties while sharing information with group members, or when students in case 2 could not share their answer for the problem-solving tasks with teacher and other students for feedback. To improve the current situation, the teachers had different requirements. The teacher in case 1 wished to receive a video instruction of examples and suggestion on how to use Classroom of the Future in implementing IALA. Teacher in case 2 did not think IALA was beneficial and doable in such a big class, yet, he would join an introduction session to know how to use the classroom better. Last, the teacher in case 3 thought IALA would take a lot of time to prepare and was not suitable for his class, however, if there was additional guidance to be provided, he would want it in the form of a short video.

Table 8.

Wilcoxon Rank Sum Test result of difference between case 1 and 2.

		Case 1	*Case 2*	*p*
1.	It is more favourable to implement IALA in Classroom of the Future than regular classroom	3.63	2.56	*.000***
2.	The space allows free interaction	3.57	3.33	*.329*
3.	Furniture is enables peer interaction	3.60	2.67	*.000***
4.	Interactive screens enable easy information sharing	*2.65*	*1.55*	*.001***
5.	The furniture can be used easily	*3.93*	*2.92*	*.000***
6.	The interactive screens can be used easily	*2.57*	*1.44*	*.008**

Agree Neutral Disagree

*p ≤ .05 **p ≤ .01 ***p ≤ .001

From the results, the research questions and hypothesis could be answered as followed:

Research question 1: In what ways does the Classroom of the Future facilitate the implementation of IALA in engineering classes?

Hypothesis 1: Space in the Classroom of the Future is **confirmed** to allow free interaction between teachers and students.

Hypothesis 2: Flexible furniture in the Classroom of the Future is **confirmed** to enable peer interaction

Hypothesis 3: Interactive screen in the Classroom of the Future is **not confirmed** to enable easy information sharing.

Research question 2: What hinders the effectiveness of the Classroom of the Future in supporting the implementation of IALA in engineering classes?

Hypothesis: Teachers' lack of technological-pedagogical-content knowledge is **confirmed** to hinder the effectiveness of Classroom of the Future.

7. Discussion

The aim of the current study was to evaluate the Classroom of the Future in supporting the implementation of IALA in undergraduate engineering classes. In order to answer the research questions, the cross-case study research was adopted. Results from the study claimed that (1) Space in the Classroom of the Future allows free interaction between teachers and students; (2) Flexible furniture in the Classroom of the Future enables peer interaction; and (3) Teachers' lack of technological-pedagogical-content knowledge hinders the effectiveness of the Classroom of the Future. The hypothesis which could not be confirmed included the interactive screen in the Classroom of the Future enables easy information sharing. The discussion is organized around the research questions and informed across cases.

Space. It was hypothesized that space in the Classroom of the Future facilitated IALA by allowing free interaction between teachers and students. This hypothesis was confirmed by teachers, students and observation. During IALA, the space of the Classroom of the Future was reviewed as open, spacious and free from obstacles, so that teachers could move around and interact with students. This is in line with Chiu's (2016) finding on what innovative learning space should be. In his research, it was suggested that the barrier in classrooms should be minimized to encourage in-class participation and engagement, and help teachers engage individual students, which benefits students' implementation of IALA. Moreover, although not yet observed and confirmed in cases, the space in Classroom of the Future could be potentially beneficial for inter-group interaction, in the same way how the space facilitated interaction between teachers and students. In addition, one added value of the space teacher acknowledged was that the spacious space provided enough room for each group so that one group's movement or noise from discussion did not disturb the others, which was why students preferred open and unconfined environment (Sommerville and Collins, 2008). This feature could be particularly beneficial in IALA such as discussion or product market when all the groups give presentations and display their products at the same time. Besides, the decent quality of the audio system helped the teachers reach all the students in the big classroom.

Furniture. It was hypothesized that flexible furniture in the Classroom of the Future enabled peer interaction. This hypothesis was confirmed by students and observation. Notably, the flexible furniture is more favorable for group IALA than individual IALA. This is in line with the findings of Granito and Santana (2016) that chairs and tables with wheels were preferred by both students and teachers for quick transition between lecture and group work. When students had group IALA, they agreed that the light furniture with wheels helped them to form group quickly. Moreover, the tables could be easily moved and combined to make a

bigger table, which assisted group members to sit around and face each other during group work. This agrees with Parsons' (2017) finding that round-table encouraged interactive learning by allowing eye contact, hand gestures, and nonverbal communication, hence, reconfigurable furniture was preferred by students (Sommerville and Collins, 2008).

Interactive screen. It was hypothesized that the interactive screen in the Classroom of the Future enabled easy information sharing. This hypothesis was not confirmed by the teacher, students and observation. The interactive screens were not beneficial during IALA in the cases, not because they did not help, but because they were not used. This is in line with Tambunan's (2014) indication that the technology was successful if the technology could be used in accordance with the purpose of utilization. The rejection to use the interactive screens in IALA by teachers and students was due to several reasons.

First, the interactive screens were not used by teachers. To explain this, Script Theory of Guidance (Fischer, Kollar, Stegmann, and Wecker, 2013) suggested that people tend to look for similar experiences to guide their understanding and acting in a new situation. Similarly, Armstrong et al. (2005) suggested that teacher applied their previous experience of similar technologies to make sense of the new technology. In this research, the teachers did not have experience in using interactive features of the screens, instead, they often used screens in classrooms to show the slides, thus, they perceived the interactive screen as a normal screen for presentation purpose. As a result, the interactive screens were used only during the lecture to mirror the slides on the main LED screen, which was similar to what Holmes (2009) found in her research when interactive screens were used primarily as a tool for multimedia presentations.

Second, the interactive screens were not used by students. Kollar, Pilz and Fischer (2014) explained that when students did not have prior experiences in new situations, they required external scripts to guide their actions. In this research, the students required for more white boards showed that they experienced difficulties and inconvenience in discussing and sharing information. Yet students did not use the interactive screen, even though the interactive screen options exceed the white board in supporting students sharing information among group members and facilitating members' contribution to the groupwork, because the students were not instructed to use this tool. The similar explanation was given by students in the cases.

Finally, technical problems could be a challenge in using technology (Johnson et al., 2016). The problems not only caused lesson disruption but also left an impression that the tool was complicated to use, and thus, should not be used in the future. There were technical problems in all three cases which made the students find the interactive screens complicated to

use. Particularly in one case, the problems could not be solved by the technical team which made the teacher and students upset with the class.

Technological-pedagogical-content knowledge. It was hypothesized that teacher's lack of TPCK would hinder the effectiveness of Classroom of the Future. This hypothesis was confirmed by teachers and observation.

In terms of pedagogical knowledge, the teachers acknowledged the effectiveness of IALA, yet, they did not think IALA were necessary and helpful in their classes or doable in a big class. This proved teachers' lack of pedagogical-content knowledge, which suggests that teachers should know how teaching approaches fit the content, and how elements of the content can be arranged for better teaching (Mishra and Koehler, 2016). Consequently, the present of IALA in engineering classes was limited. Even though there were some IALA, particularly intra-group discussion, problem-solving task, and group programming in the observed classes, teachers did not implement IALA properly. For instance, teachers did not ask the students to share their answer or result of the group discussion. As a result, the need to use the special features of the Classroom of the Future was limited. For instance, in normal lecture, the teacher only stays at the front area for lecturing, students will not witness the benefit of space in allowing the teacher to freely approach to students or allowing groups to interact with each other. Also, when students attend a normal lecture, they do not need to move the furniture around, instead, they use the furniture in the Classroom of the Future as the normal one in the regular classroom, hence, they will not experience the benefits from the light and flexible furniture. A similar scenario is expected to happen with the interactive screen. In a normal lecture, a big screen is enough for teachers to show the content; students do not need an interactive screen to share the information between group members or with other groups. Therefore, without knowing how to incorporate IALA in engineering classes, teachers will not implement properly IALA, the features of the Classroom of the Future would not have a chance to be useful.

In terms of technological knowledge, the teachers in all cases did not receive useful information on how to use the interactive screen in the Classroom of the Future. As a result, the teachers were not aware of the special features of the interactive screen, did not think the interactive screen was necessary, and thus, did not consider using it in IALA or instruct the students to use it. This is in line with the finding of Ertmer et al. (2012); Habiku et al. (2012); and Gobel and Kano (2013) that knowledge in technology was essential for teacher's belief toward the benefit and relevance of technology in teaching and learning. This also proved

teachers' lack of technological-content knowledge, which suggests how the subject matter can be changed by the application of technology, and technological pedagogical knowledge, which indicates how teaching might change as the result of using the technologies (Mishra and Koehler, 2016). Without the understanding of the technology, teachers will not know how, when and why to use the the interactive screen in the classroom (Burke, 2005), and not devote time and effort for a new technology (Gilakjani, 2013). Consequently, the potential of the technology would not be realised and used in the classroom (Armstrong et al., 2005).

To sum up, Teachers lack knowledge about technology, pedagogy and content in related with each other. As a result, they have limited need and skills to make use of the special features of the Classroom of the Future, especially the interactive screen.

From the above discussion, the research questions could be answered as follows.

Classroom of the Future facilitates the implementation of IALA in engineering classes in several ways. First, space in the Classroom of the Future is open, spacious, and free from obstacles so that teachers could move around to give students instruction, guidance, feedback during IALA. Spacious space also provides essential room for each group, so that one group's movement or noise during the IALA do not disturb the others. Second, flexible furniture with wheels helps students to form groups quickly to shift from different activities. Tables can also be easily moved and combined to make a bigger table for groups, which enables peer interaction. Decent quality of the sound system also supports the teaching and learning in the Classroom of the Future. Overall, the Classroom of the Future is more favourable compared to regular classrooms, only when the appropriate teaching and learning method, such as group IALA, is implemented.

Factor which hinders the effectiveness of the Classroom of the Future in supporting the implementation of IALA in engineering classes is mostly the lack of knowledge and experience from teachers and students in IALA and in working with innovative learning space. Particularly, when teachers do not believe the IALA is beneficial for the subject matter, they will not incorporate it in their class, and hence, do not need special support from the innovative learning space. Also, when teachers do not know why, when and how to use the interactive screens, they will not consider using them or instruct the students to use them in IALA. The inexperience with new technology might also lead to lesson disruption due to technical problems.

8. Conclusion and recommendation

This research aimed at evaluating the Classroom of the Future in supporting the implementation of IALA in engineering classes. A cross-case study approach was applied to investigate which features worked and what hindered the effectiveness of those features. Results of the research showed that, space and furniture in the Classroom of the Future was effectively used, while the interactive screen needed extra support to be used in accordance with its utilization purpose. The Classroom of the Future would be more effective when the appropriate teaching and learning method is implemented.

Based on major findings, it could be seen that additional training and support for teachers to use the Classroom of the Future effectively is urgent. The crucial role of teachers in the effective use of the Classroom of the Future was acknowledged by students. Students indicated that the Classroom of the Future could be favourable for IALA only when 'teachers do have to know what the possibilities of the room are and how to implement these', so that 'suitable learning methods would be used'. Similarly, in Granito and Santana's (2016) research, students believed that teachers should be trained in how to use the technology, to parallel with the paradigm shift in education. Therefore, the management team of the Classroom of the Future and faculties should work together to deliver sufficient training and guidance to teachers to help them integrate technology into the classroom successfully. The guidance should focus on examples of IALA suitable with engineering domain, how the specific IALA benefits the topic and how technology can be used to facilitate that IALA. Group IALA should be prioritised because the Classroom of the Future is more beneficial for students working in groups. It should also be noted that added values of IALA need to be emphasized because the teachers considered lectures enough for students to pass the exams. Examples of how IALA could be implemented with the support from the interactive screen would save valuable time for teachers from brainstorming and designing new activities since the busy schedule is another concern of the teachers in the three cases, as well as most University professors (Ralston et al., 2017). Notably, different teachers had different requirement on what form of instruction they wanted to receive, particularly, video, manual or face to face instruction. Therefore, the guidance should come from various formats and materials, such as video-based and text-based instruction to suit different teachers' preference. Furthermore, to prevent lesson being disrupted due to technical problems, immediate support should be available when technical difficulties arise prior to and during lessons to facilitate the use of the ICT (as cited in Smith et al., 2005). Moreover, Kollar et al. (2014) indicated that clear instructions on how to use the new technology should be provided to students. The instructions are most often from the teachers,

yet, it is not necessarily always the case. To encourage the students to use the interactive screen during IALA, the instruction can be given directly to students through a notice or a manual attached to the interactive screen, which let the students know that they can use the interactive screens, what they can do with it and how to use it. In the end, the students are the one implementing IALA so, they should decide which support is necessary and helpful to their own learning.

Besides, there are several minor recommendations for improvement. Suggestions are made on the elements which are favourable for both lecture and IALA because the lecture is still the standard and to be enhanced by IALA in a class, which agrees with Felder and Brent's (2009) suggestion on incorporating several learning activities throughout the lecture. In addition, Kirschner, Sweller, and Clark (2006) suggested that students should construct knowledge after being given adequate information, hence, students, especially novice ones, should be provided with direct instructional guidance that fully explains the concepts and procedures that students require to learn before they apply the knowledge in IALA. Therefore, a flexible classroom, which is useful for both lecture and IALA, should be provided rather than making all the classroom specifically for only active learning purpose (Hyun et al., 2017). This is also in agreement with the orientation in which the Classroom of the Future is a model project for what the University of Twente would look like in a few years, thus, it should be favourable for lectures as well. Finally, a classroom which can be used for various purposes will be more beneficial, compared to classrooms of different functions which require students and teacher to move when they change the teaching and learning method.

First, the biggest concern from the students is that the space in the Classroom of the Future is too crowded when there are more than 90 students. More people in the classroom means less space for free movement and interaction, which no longer benefits IALA. As a result, classrooms with small workspace made students cramp and left a negative influence on their learning (Granito and Santana, 2016). Therefore, the available seats in the Classroom of the Future should be reduced from the current number, which is 120, to achieve its best impact. Furthermore, the room was reviewed of having too many elements, which distracted or blocked the view of students when they faced the main LED screen for lectures. Therefore, the socket poles in the Classroom of the Future should be replaced with the underground or wall sockets, unless the socket poles have features that are more important and worth the small inconvenience.

Second, it could be seen that although all the tables are light, only some have wheels. Therefore, normal tables should be replaced by tables with wheels to better facilitate quick

group formation. Another drawback of the furniture reported by teachers and students was that there were not enough tables for 120 students. It could be understood that the Classroom of the Future was designed for the active group learning purpose, in which, two tables can be used for a group of six students facing each other, hence, 40 tables are enough for 120 students. However, a class often includes a lecture in half or two third of the time, followed by IALA. In lecture time, when all students face the main LED screen, two students fit in one table, hence, 40 tables are enough for 80 students only. Yet, more tables are not suggested to be supplemented, as the previous discussion about space mentioned, the Classroom of the Future should not contain too many students and tables. Or else, it would be too crowded, and thus, special features of the space, which allows free interaction, would be sacrificed. Therefore, the seat capacity of the Classroom of the Future should be announced less than it is now. Finally, there was an issue with tables of different sizes. The tables of bigger width create a bigger gap between group members, which hinders intra-group discussion. Thus, small-width tables with wheels should be used in the Classroom of the Future.

Third, the interactive screen was reported to reflect the sunlight, which made it difficult to see the content on the screen. This implied for the need to the repositioning of the interactive screens and effective blinds (as cited in Smith et al., 2005). Besides the issues with the interactive screen, opinions regarding the main LED screen were also recorded. Accordingly, the teachers and students were not pleased with the fact that the main LED screen was made from four separate screens, which formed a cross over the slides. Moreover, the teachers could not use a laser pointer to point or highlight a certain part on the slides that they wanted the students to focus on. Finally, the students reported that the main LED screen was too small for students at the back of the class to see. It could be argued that the interactive screens could replace the main LED screen in helping students at the back to see the slides, yet, teacher's actions and demonstration could not be shown on the interactive screens. To sum up, other options, such as a bigger screen or a large white screen and beamer, should be considered to replace the current main LED screen to serve teachers' and students' needs in lectures.

Finally, students requested more white boards to make note and share the result of the discussion among group members. White boards also enable easier creation of shared drawings, models, formulas, equations, answers for Mathematics problems compared to laptops. Hence, tools, such as whiteboards or flip chart, which help students create products other than text should be equipped. Other than that, the teachers and students did not propose any other tool to help them implement IALA. However, recommendations for the future of the Classroom of the Future can be found in Groff's (2013) list of first-order innovations, which

included laptops, netbooks, tablets, interactive screens, digital cameras, scanners, projectors; and second-order innovations, which consisted of remote-response systems, mobile/handheld computing, programming applications, Pico projectors. He explained that the first-order innovations had been common in many innovative learning environments and proved to add value in education, while the second-order innovations were potentially beneficial and would likely to see the increased application in the years to come. Nonetheless, it might not be effective and efficient to equip more technologies when the current facilities have not been used at its full potential. Hence, teachers and students should be supported to master the present ICT in the Classroom of the Future before moving to the next stage. Moreover, the further provision of technologies should be based on careful analysis of teachers' and students' needs in IALA rather than merely on the functions of the facilities.

To sum up, the effectiveness of Classroom of the Future in supporting the implementation of IALA in engineering classes can be improved by (1) giving sufficient guidance following TPCK model to teachers; (2) giving instruction on how to use the interactive screen to students; (3) providing immediate technical support when teachers and students are in need; (4) maintaining spacious space while making it less crowded with students and unnecessary elements; (5) maintaining light furniture with wheels; (6) taking effective method to prevent the interactive screen from reflecting the sunlight; (7) considering using a larger screen to replace the main LED screen; and (8) considering providing more white boards or flip charts.

The result and discussion of this research could be considered by the management team of the Classroom of the Future and engineering faculties at the University of Twente. Caution should be taken when interpreting these results in other settings because the themes and observations come from a small sample. Future research should focus on developing guidance and training for teachers to effectively use the interactive screen in IALA following TPCK framework. Similar evaluations could be conducted with other study programs in other faculties at the University of Twente.

Reference

Armstrong, V., Barnes, S., Sutherland, R., Curran, S., Mills, S., & Thompson, I. (2005). Collaborative research methodology for investigating teaching and learning: the use of interactive whiteboard technology. *Educational review*, *57*(4), 457-469. doi: 10.1080/00131910500279551

Beauchamp, G., & Parkinson, J. (2005). Beyond the 'wow' factor developing interactivity with the interactive whiteboard (n.d.). Retrieved from http://karsenti.scedu.umontreal.ca/archives/tbi-recherches/Beyond.pdf

Beichner, R. J., Saul, J. M., Abbott, D. S., Morse, J. J., Deardorff, D., Allain, R. J., Bohnam, S., W., Dancy, M., H., & Risley, J. S. (2007). The student-centered activities for large enrolment undergraduate programs (SCALE-UP) project. *Research-based reform of university physics*, *1*(1), 2-39.

Bell, M. A. (2002). Why use an interactive whiteboard? A baker's dozen reasons. Retrieved from https://www.teachers.net/gazette/JAN02/mabell.html

Berggren, K. F., Brodeur, D., Crawley, E. F., Ingemarsson, I., Litant, W. T., Malmqvist, J., & Östlund, S. (2003). CDIO: An international initiative for reforming engineering education. *World Transactions on Engineering and Technology Education*, *2*(1), 49-52.

Biggs, J. (2003). Aligning teaching for constructing learning. *Higher Education Academy*,1-4.

Brooks, D. C. (2012). Space and consequences: The impact of different formal learning spaces on instructor and student behaviour. *Journal of Learning Spaces*, *1*(2), n2.

Burke, J. (2005). Technology Standards for Teachers. (n.d.). *Educational Technology Cooperative*. Retrieved from http://www.sreb.org/Programs/EdTech/EdTechindex/asp

Chi, M. T., & Wylie, R. (2014). The ICAP framework: Linking cognitive engagement to active learning outcomes. *Educational Psychologist*, *49*(4), 219-243.

Chiu, P. H. P. (2016). A technology-enriched active learning space for a new gateway education programme in Hong Kong: A platform for nurturing student innovations. *Journal of Learning Spaces*, *5*(1).

Classroom of the Future. (n.d.). Retrieved from https://4tu-iframe.studiotast.com/project/61

Cohen, D. K., & Ball, D. L. (2001). Making change: Instruction and its improvement. *Phi Delta Kappan*, *83*(1), 73-77.

de Kuyper, P. (2015). Classroom of the Future in Gallery. (n.d.). Retrieved from http://www.utoday.nl/news/60925/Classroom_of_the_Future_in_Gallery

de Silva, C. R., Chigona, A., & Adendorff, S. A. (2016). Technology Integration: Exploring Interactive Whiteboards as Dialogic Spaces in the Foundation Phase Classroom. *Turkish Online Journal of Educational Technology-TOJET*, *15*(3), 141-150.

Dori, Y. J., & Belcher, J. (2005). How Does Technology-Enabled Active Learning Affect Undergraduate Students Understanding of Electromagnetism Concepts? *Journal of the Learning Sciences,14*(2), 243-279. doi:10.1207/s15327809jls1402_3

Ertmer, P. A., Ottenbreit-Leftwich, A. T., Sadik, O., Sendurur, E., & Sendurur, P. (2012). Teacher beliefs and technology integration practices: A critical relationship. *Computers & Education*, *59*(2), 423-435.

Ertmer, P. A., Ottenbreit-Leftwich, A., & York, C. S. (2006). Exemplary technology-using teachers: Perceptions of factors influencing success. *Journal of Computing in Teacher Education*, *23*(2), 55-61.

Felder, R. M., & Brent, R. (2009). Active learning: An introduction. *ASQ higher education brief*, *2*(4), 1-5.

Fischer, F., Kollar, I., Stegmann, K., & Wecker, C. (2013). Toward a script theory of guidance in computer-supported collaborative learning. *Educational psychologist*, *48*(1), 56-66.

Gilakjani, A. P. (2013). Factors contributing to teachers' use of computer technology in the classroom. *Universal Journal of Educational Research*, *1*(3), 262-267.

Glover, D., Miller, D., Averis, D. & Door, V. (2007). The evolution of an effective pedagogy for teachers using the interactive whiteboard and modern languages: An empirical analysis from the secondary sectors. *Learning, Media and Technology*, 32(1), 5-20.

Gobel, P., & Kano, M. (2013). Student and Teacher Use of Technology at the University Level. *International Association for Development of the Information Society*.

Gol, O., & Nafalski, A. (2007). *Collaborative learning in engineering education* (Doctoral dissertation, Unesco, Internationa Centre for Engineering Education).

Gordon, R. (1998). Coding interview responses. *Basic Interviewing Skills. Waveland Pr Inc*, 183-199.

Granito, V. J., & Santana, M. E. (2016). Psychology of learning spaces: Impact on teaching and learning. *Journal of Learning Spaces*, *5*(1).

Groff, J. (2013). Technology-rich innovative learning environments. *OCED CERI Innovative Learning Environment project*, 1-30.

Habibu, T., Abdullah-Al-Mamun, M., & Clement, C. (2012). Difficulties faced by teachers in using ICT in teaching-learning at technical and higher educational institutions of Uganda. *International Journal of Engineering*, *1*(7), 1-10.

Harvey, E. J., & Kenyon, M. C. (2013). Classroom seating considerations for 21st century students and faculty. *Journal of Learning Spaces*, *2*(1).

Holmes, K. (2009). Planning to teach with digital tools: Introducing the interactive whiteboard to pre-service secondary mathematics teachers. *Australasian Journal of Educational Technology*, *25*(3), 351-365.

Hyun, J., Ediger, R., & Lee, D. (2017). Students' Satisfaction on Their Learning Process in Active Learning and Traditional Classrooms. *International Journal of Teaching and Learning in Higher Education*, *29*(1), 108-118.

Johnson, A. M., Jacovina, M. E., Russell, D. G., & Soto, C. M. (2016). Challenges and Solutions when Using Technologies in the Classroom. In *Adaptive Educational Technologies for Literacy Instruction* (pp. 13-30). Routledge.

Karacop, A., & Diken, E. H. (2017). The Effects of Jigsaw Technique Based on Cooperative Learning on Prospective Science Teachers' Science Process Skill. *Journal of Education and Practice*, *8*(6), 86-97.

Kershner, R., Mercer, N., Warwick, P., & Staarman, J. K. (2010). Can the interactive whiteboard support young children's collaborative communication and thinking in classroom science activities?. *International Journal of Computer-Supported Collaborative Learning*, *5*(4), 359-383.

Kirschner, P. A., Sweller, J., & Clark, R. E. (2006). Why Minimal Guidance During Instruction Does Not Work: An Analysis of the Failure of Constructivist, Discovery, Problem-Based, Experiential, and Inquiry-Based Teaching. *Educational Psychologist,41*(2), 75-86. doi:10.1207/s15326985ep4102_1

Knight, D. W., Carlson, L. E., & Sullivan, J. F. (2007, June). Improving engineering student retention through hands-on, team based, first-year design projects. In *Proceedings of the International Conference on Research in Engineering Education*. Honolulu, HI.

Kollar, I., Pilz, F., & Fischer, F. (2014). Why it is hard to make use of new learning spaces: a script perspective. *Technology, Pedagogy and Education*, *23*(1), 7-18.

Lagares, M., & Reisenleutner, S. (2017). 9Rotating poster presentations. *Innovative language teaching and learning at university: enhancing employability*, 79.

Lee, K. S., & Chavis, D. M. (2012). Cross-case methodology: Bringing rigour to community and systems change research and evaluation. *Journal of Community & Applied Social Psychology*, *22*(5), 428-438.

Levy, P. (2002). Interactive whiteboards in learning and teaching in two Sheffield schools: a developmental study. *http://www. shef. ac. uk/eirg/projects/wboards*.

LoPresto, M. C., & Slater, T. F. (2016). A new comparison of active learning strategies to traditional lectures for teaching college astronomy. *Journal of Astronomy & Earth Sciences Education*, *3*(1), 59-76.

McKenney, S., & Reeves, T.C. (2012). Conducting educational design research. New York, NY: Routledge

Medscheduler. (n.d.). Reservations & Features - Medscheduler - Stanford University School of Medicine. Retrieved from http://med.stanford.edu/medscheduler/features.html

Mishra, P., & Koehler, M. J. (2006). Technological pedagogical content knowledge: A framework for teacher knowledge. *Teachers college record*, *108*(6), 1017.

Morgan, S. J., Pullon, S. R., Macdonald, L. M., McKinlay, E. M., & Gray, B. V. (2017). Case study observational research: a framework for conducting case study research where observation data are the focus. *Qualitative health research*, *27*(7), 1060-1068.

Najafi, M., Motaghi, Z., Nasrabadi, H. B., & Heshi, K. N. (2016). Debate learning method and its implications for the formal education system. *Educational Research and Reviews*, *11*(6), 211-218.

Kuipers, R. (2018). Nieuw beheer, nieuwe start voor Classroom of the Future. (n.d.). Retrieved from http://www.utoday.nl/news/65737/nieuw-beheer-nieuwe-start-voor-classroom-of-the-future

Parsons, C. S. (2017). Reforming the Environment: The Influence of the Roundtable Classroom Design on Interactive Learning. *Journal of Learning Spaces*, *6*(3), 23-33.

Pashler, H., McDaniel, M., Rohrer, D., & Bjork, R. (2008). Learning styles: Concepts and evidence. *Psychological science in the public interest*, *9*(3), 105-119.

Pedro, N. (2017). Redesigning Learning Spaces: What Do Teachers Want for Future Classrooms?. *International Association for Development of the Information Society*.

Phillipson, A., Riel, A., & Leger, A. B. (2018). Between Knowing and Learning: New Instructors' Experiences in Active Learning Classrooms. *The Canadian Journal for the Scholarship of Teaching and Learning*, *9*(1), 4.

Rabionet, S. E. (2011). How I Learned to Design and Conduct Semi-Structured Interviews: An Ongoing and Continuous Journey. *Qualitative Report*, *16*(2), 563-566.

Radcliffe, D. (2009). A pedagogy-space-technology (PST) framework for designing and evaluating learning places. In *Learning spaces in higher education: Positive outcomes by design. Proceedings of the Next Generation Learning Spaces 2008 Colloquium, University of Queensland, Brisbane* (pp. 11-16).

Ralston, P. S., Tretter, T. R., & Brown, M. K. (2017). Implementing Collaborative Learning across the Engineering Curriculum. *Journal of the Scholarship of Teaching and Learning*, *17*(3), 89-108.

Rowley, J. (2002). Using case studies in research. *Management research news*, *25*(1), 16-27.

Sawers, K. M., Wicks, D., Mvududu, N., Seeley, L., & Copeland, R. (2016). What Drives Student Engagement: Is it Learning Space, Instructor Behavior or Teaching Philosophy?. *Journal of Learning Spaces*, *5*(2).

Seechaliao, T. (2017). Instructional strategies to support creativity and innovation in education. *Journal of Education and Learning*, *6*(4), 201.

Smith, H. J., Higgins, S., Wall, K., & Miller, J. (2005). Interactive whiteboards: Boon or bandwagon? A critical review of the literature. *Journal of Computer Assisted Learning*,*21*(2), 91-101. doi:10.1111/j.1365-2729.2005.00117.x

Somerville, M. M., & Collins, L. (2008). Collaborative design: a learner-centered library planning approach. *The Electronic Library*, *26*(6), 803-820.

Stake, R. E. (2010). *The art of case study research*. Thousand Oaks, CA: Sage Publ.

Steadman, R. G. (2015). Establishing an Atmosphere for Critical Thinking in the Online Classroom. *Journal of Instructional Research*, *4*, 3-11

Stoltzfus, J. R., & Libarkin, J. (2016). Does the Room Matter? Active Learning in Traditional and Enhanced Lecture Spaces. *CBE—Life Sciences Education*,*15*(4). doi:10.1187/cbe.16-03-0126

Student incubator. (n.d.). Retrieved from http://www.starthubwageningen.nl/

Tambunan, H. (2014). Factors Affecting Teachers' Competence in the Field of Information Technology. *International Education Studies*, *7*(12), 70.

Ünal, E., & Çakir, H. (2017). Students' Views about the Problem Based Collaborative Learning Environment Supported by Dynamic Web Technologies. *Malaysian Online Journal of Educational Technology*, *5*(2), 1-19.

Wiggins, B. L., Eddy, S. L., Grunspan, D. Z., & Crowe, A. J. (2017). The ICAP active learning framework predicts the learning gains observed in intensely active classroom experiences. *AERA Open*, *3*(2), 2332858417708567.

Wismath, S. L., & Orr, D. (2015). Collaborative Learning in Problem Solving: A Case Study in Metacognitive Learning. *Canadian Journal for the Scholarship of Teaching and Learning*, *6*(3), 10.

Wood, C. (2001). Interactive whiteboards–a luxury too far. *Teaching ICT*, *1*(2), 52-62.

Yin, R. K. (2014). *Case study research: Design and methods*. London: Sage Publication.

APPENDIX A – Information letter

Dear lecturers,

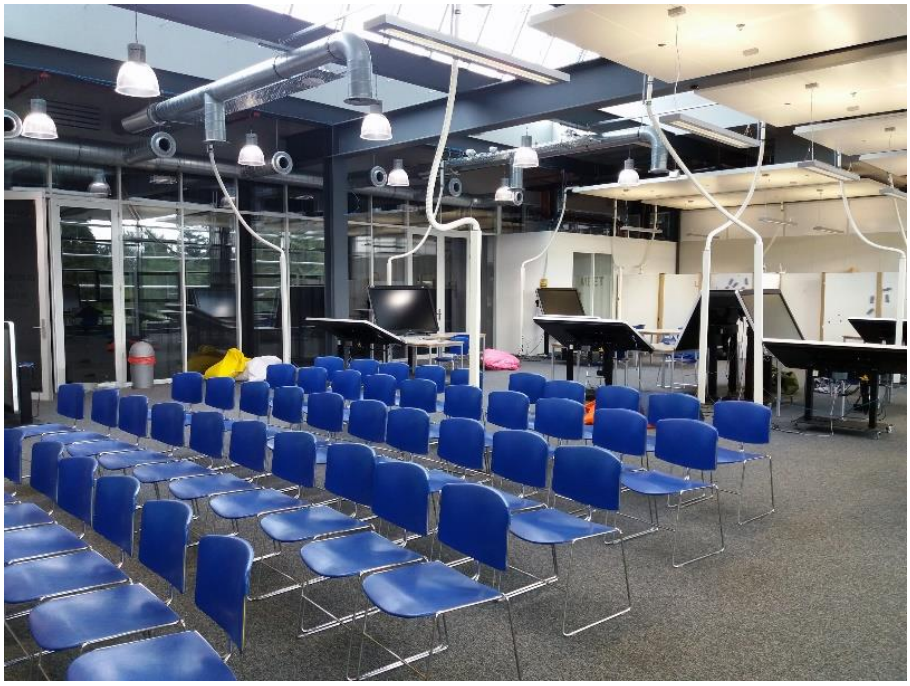
We would like to take a moment to welcome you to Classroom of the Future for your education in the coming quartile. Due to the lack of large rooms at the university, this quartile you will be using Classroom of the Future for your lecture/module. The Classroom of the Future is created to stimulating active (group) learning. The remarkable, uneven setup of the room has a positive effect on the processes of teacher - student interaction, interaction among students in a group (collaboration)and interaction between/among groups.

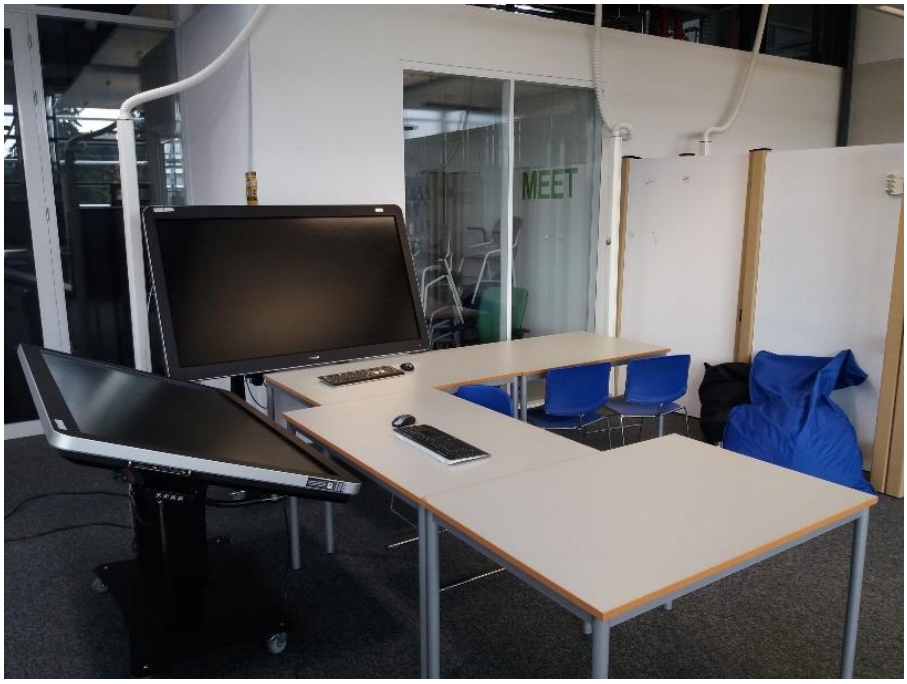
To help us reach these goals for the education in Classroom of the future we need your help so we can help you (and your colleagues that will come after you)

- **Setup of the room**: the room has a default setup. If you want to change it for your class, you are welcome to do so, just make sure that before you leave the room, everything is back to the original setup! (see the picture below)

- **Use of the touch screens**: there are 16 C touch screens in the room that can be used by students and lecturers. LISA can assist you in setting it up, reserve this in advance so they can plan accordingly. You can request this in Planon. Please note that DesignLab/DreamTeam is not available to help you with the set-up of the screens.

- **Technology:** the room is equipped with a large plenary screen. You can bring your own laptop and plug it to the screen. If you need assistance for doing so, please contact LISA.




MEET

APPENDIX B – Survey

EVALUATE CLASSROOM OF THE FUTURE

This survey was designed to measure how Classroom of the Future support the implementation of active learning activities. Active learning activities refer to anything course-related that you have to do in class other than watching, listening and taking notes (Felder and Brent, 2009). For example, presentation, discussion, debate, problem-solving task, etc.

Please read the questions and deliberate carefully before giving your answers.

1. I am a … a. Bachelor student b. Master student
2. I am … a. Male b. Female
3. I am … years old

For questions from 4 to 11, please rank your opinion from 1 to 5

1 = "completely disagree" and 5 = "completely agree"

Enter an 'x' in the appropriate box for each statement.

Statement	1	2	3	4	5
4. Overall, it is more favourable to implement active learning activities in Classroom of the Future than regular classroom.					
5. The teacher was able to approach comfortably to the students.					
6. The flexible furniture helped me to form group quickly.					
7. The flexible furniture helped me to sit in round to discuss with group members easily					
8. The interactive screens were convenient for sharing information					
9. The interactive screens were convenient for sharing presentation					
10. I could use the flexible furniture easily					
11. I could use the interactive screens easily					

For questions from 12 to 17, please share your thoughts on each question.

12. Did you experience any other **benefits** of space, furniture, video wall, interactive screens, white boards that have not been mentioned? If yes, please specify.
13. Did you experience any **difficulties** when using space, furniture, video wall, interactive screens, whiteboards? If yes, please specify.
14. Is there any facility in Classroom of the Future that you **did not use** while doing the active learning activities? Why didn't you use it?
15. Were there any moments when you found it **difficult** to implement active learning activities? Do you suggest any facility that can help you to solve the problem?
16. To sum up, do you think it is more **favourable** to implement active learning activities in the Classroom of the Future than in the regular classroom? Please specify.
17. Do you suggest any **learning activities** that you think will suit Classroom of the Future?

THANK YOU!

APPENDIX C – Semi-structured interview framework

	Questions	Note
Pedagogy	Why did you choose to use Classroom of the Future? Did you achieve the initial learning goals? How did you learn to work in Classroom of the Future? Did you have any support?	
Space	Did you have the space appropriate for your learning purposes? Did you have enough space to approach and interact with students? Were there any other benefits that you experience when you used the space? What were the difficulties when you used the space?	
ICT	Were you able to deliver the lesson by using the available facilities? What were the benefits did you experience when you used the facilities? What were the difficulties when you used the facilities? With the available facilities, are you inspired to design some learning activities for students? Do you think the facilities can benefit the implementation of the active learning activities? (From observation) Why didn't you let the students use the interactive screens while they are doing the learning activities?	
Overall	Do you think the space and facilities can adapt to various learning activities? How do you compare between Classroom of the Future and traditional classrooms? Especially in supporting active learning activities?	
Suggestion	Are you able to give instruction to students on how to use the space, furniture, facilities? What do you think about active learning activities? What do you think will help the students do it better? If you are required to incorporate more activities, what do you think? What do you consider when designing them? Where do you get the ideas from? What helps you to design them? Which learning activities do you think work best in this classroom? Which learning activities do you think are not appropriate in this classroom? What should be done to help teachers to use facilities in Classroom of the Future? (Guideline - digital or paper, development program - long or short, in what form, etc) Did you notice any difficulties students have when they were doing the learning activities? Do you suggest any specific facility that should be in Classroom of the Future?	

APPENDIX D – Class observation checklist

Class: _____ Date and Time: _____

	Observation	**NOTE**
Pedagogy	How many students were there? _____ How many learning activities did the students have? _____ How much time in total did the learning activities take? _____	
Space	How many times did students interact with teacher? _____ Did teacher move around the class comfortably? _____	
Furniture	What was the average amount of time students need to switch between learning activities? _____ Did students form round-tables? _____ Did they have any difficulties? _____	
ICT	Did students use the interactive boards to search information? _____ Did students use the interactive boards to share their product? _____ Was there any time when they needed to use ICT but did not? _____ Did they have any difficulties? _____	
Overall	Did the students focus on their class? _____ Did the students do things irrelevant? _____ Were the students feel inconvenient or uncomfortable anytime? _____	
Suggestion	Did teacher give clear instruction for each learning activity? _____ Did teacher give clear instruction on how to use the facilities? _____	