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EXEMPLARY TECHNOLOGY INCORPORATED CONTEMPORARY ACTIVE LEARNING ENVIRONMENTS FOR STEM COURSES

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ABSTRACT: Unprecedented innovations have been experienced since the second half of the twentieth century although there have not been fundamental changes in learning environments throughout the history. The reasons of these changes can be grouped mainly into two categories: 1) The development of new learning-teaching approaches such as constructivism, active learning, lifelong learning, etc. 2) The fast incorporation of technology into education like in every part of our life. More developments in learning environments will not be surprising in the near future.

This study aims to present and analyze contemporary active learning classrooms (ALCs) which are technology incorporated, large enrolled, student-centered, and highly interactive. For this aim, literature review has been carried out about technology incorporated ALCs, which are being innovated continually and designed especially for STEM courses, and prominent contemporary classrooms have been compiled. Then, some ALCs such as SCALE-UP, TEAL, TILE and Next-Gen ALC v2.0 have been deeply analyzed in terms of their physical environment, pedagogical approach, teaching and learning processes, etc. Moreover, traditional classrooms and technology incorporated contemporary ALCs have been compared. It is concluded that the use of these ALCs should be disseminated and instructors should be prepared to guide and facilitate learning in these classrooms.

Keywords: Active learning, contemporary classrooms, technology incorporated, STEM courses, SCALE-UP

INTRODUCTION

For long years, governments have been allocating a large portion of their budgets in education in order to increase the quality of learning and teaching in schools. For this purpose, new schools are being constructed, educational and curricular reforms are taking place, and teacher education programs are being updated. However, the results show that the outcomes are not consonant with the efforts (Gonzalez & Kuenzi, 2012).

There are many reasons of this failure and learning environments may be one of these. While curriculum is constructivist and classrooms are modern and equipped with some technological devices like smart boards and computers, classroom design is still traditional in many schools, in which desks are located one after another and the teacher is in front of the classroom. This design also negatively effects especially the implementation of the constructivist curriculum which is student-centered and supports active learning in its nature. Park & Choi (2014) specify “educational spaces convey an image of educational philosophy about teaching and learning”. They indicate that traditional classrooms may be a representation of educational philosophy of essentialism which focuses more on “injecting content into students’ brain” rather than having them active and enabling them construct the knowledge. Therefore, it is possible to say that students cannot really be active in these traditional classrooms.

The idea of classroom dates back to ancient Greek where students surrounded their teachers during Socratic dialogues. There was not a regular classroom space, teachers and students came together in an irregular shape. Medieval universities were first to use structured spaces for education, there were two vertical lines of desks facing each other. Then linear rows of desks started to emerge where the teacher stood at the front center of the space. The term lecture, *lectus* in Latin, as a means of delivering the original knowledge through instructor’s

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reading to students was important in those days because paper and books were rare. With the industrial revolution, a need for bigger classrooms arises due to the increase in the number of the students to be educated, and the traditionally designed classrooms were shaped (Park & Choi, 2014). This traditional layout is still used in a widespread manner in many classrooms today (Parsons, 2015, p. 18).

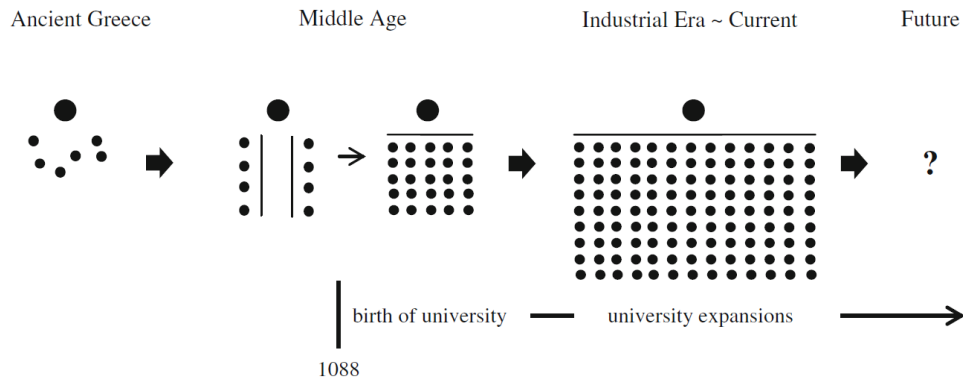


Figure 1. Historical changes in classroom design (Park & Choi, 2014)

Strange & Banning (2001, p. 12) states that physical environment effects learning and development processes. Even if it is a technology incorporated classroom, the design of the classroom will hinder active learning in a traditional one because academic architecture has its own hidden curriculum, and the design and construction of the classrooms effect learning (Orr, 1993). In order for retention and achievement, students should involve actively in peer and student-faculty interaction (Astin, 1993) and this can be done thanks to active learning classrooms (ALCs).

ALCs are technology incorporated collaborative learning environments which support constructivist educational paradigms (Charles, Whittaker & Lasry, 2014). In ALCs, teachers' role of relaying information shifts to learning coach and facilitator. These classrooms also promote collaborative learning and teamwork, active discussion and encourage students to talk and participate more (Alexander et. al., 2009). Therefore, in order to achieve these goals, ALC furnishings and architecture are designed intentionally in a different way shifting the focus toward students' collaboration and reshaping the traditional authority structures (Charles, Whittaker & Lasry, 2014). They also consist many technological devices to provide an active learning opportunity (Erol, Ozcan & Luft, 2016) and visualization, connectivity, sharing and artifact creation (Charles, Whittaker & Lasry, 2014). A current ALC may be depicted as in Figure 2 to replace the question mark in Figure 1.

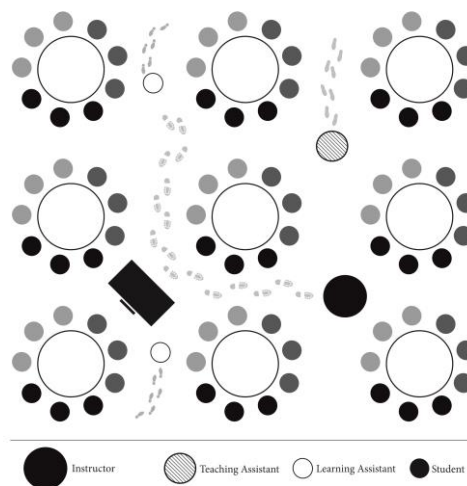


Figure 2. Contemporary active learning classroom design

As shown in Figure 2, the traditional idea of instruction, in which teacher is the resource of the knowledge and s/he teaches by “lecturing” and students learn by sitting on their desks, is flipped in ALCs. In these flipped classrooms, the teacher is not the authoritative figure in front of the students; instead s/he is the facilitator and coach of the learning. The teacher walks around the classroom, works with the students on the tasks and guides and discusses with them. In some ALCs, there may be some teaching and learning assistants who help both

students and teachers during the activities. In these classes, students sit in groups and face to face rather than one after another.

Before the construction of contemporary ALCs, there have been some initiatives such as Workshop Physics, Open Laboratory, and Peer Instruction.

Initiatives of ALC Implementations

In a *workshop* physics classroom, which was firstly implemented by Dickinson College, all lectures are taught in a laboratory with new computer technology. Students preferred workshop courses (Singer, Nielsen & Schweingruber, 2012, p. 127) and their success was better on the conceptual exams, but not in problem solving (Laws 1991, 2004). *Peer Instruction* approach (a Harvard University initiation) has been shown to boost conceptual understanding and problem-solving abilities and to provide instructors with valuable feedback on their teaching (Mintzes & Leonard, 2006). *Open Laboratory* allows students flexibility in scheduling laboratory attendance and permits students to spend more time if necessary to complete lab. The system also encourages the students use of visual media which is less personnel dependent instruction (Godbey, Otieno & Tofan, 2006). *Interactive Lecture Demonstrations* (initiated in University of Colorado) are designed to enhance conceptual learning through active engagement of students in learning process. Students observe real physics demonstrations, make predictions about the outcomes on a prediction sheet, and collaborate with fellow students by discussing their predictions in small groups, and then examine the results of the live demonstration (Sokoloff & Thornton, 2004).

Active learning has been reported to increase academic performance in Science, Technology, Engineering and Mathematics (STEM) courses (Freeman et. al., 2014), therefore, ALCs are widely used in STEM education. In an educational view STEM education involves more inquiry and project-based approach than traditional lecture-based teaching activities (Breiner et. al., 2012). STEM contains educational practices both in formal and informal settings across all levels from pre-school to post-doctorate (Gonzalez & Kuenzi, 2012). These are generally active learning practices that promote student engagement in learning process, increase academic performance and facilitate interaction between the students and instructors (Erol, Ozcan & Luft, 2016).

Aforementioned ALC initiatives fall under *studio* style classroom. In these classrooms, physical design of the room is different; students sit together and look at each other (Perkins, 2005) and the environment is quite interactive (Gottfried, 2007). Although it covers small number of topics in the course book, it enables students to comprehend the concepts deeply and supplies a higher order thinking skills because lab and lecture are combined and no major problems were reported by the researchers who studied in it (Perkins, 2005). The pedagogy of this classroom is based on peer instruction (Kohl, 2012) learning cycles, active learning, scientific research, and cooperative learning (Gottfried et. al., 2007). The research show that studio teaching promotes better learning, improve student attitudes, and result in better grades (Beichner & Saul, 2003; Perkins, 2005), gains in problem-solving skills and exam performance (Kohl & Kuo, 2012).

Aim

Among the studio type classrooms, some are commonly and successfully implemented, especially in STEM courses, such as SCALE-UP (Student Centered Active Learning Environments Upside Down Pedagogies, initiated in North Caroline State University), TEAL (Technology Enabled Active Learning, initiated in Massachusetts Institute of Technology), TILE (Transform, Interact, Learn, Engage, initiated in University of Iowa), and Next-Gen ALC v2.0 (Next Generation Active Learning Classroom, initiated in Dawson College). These ALCs have very similar characteristics with each other. They are technology-enhanced and contemporary environments that promote active and engaged learning. The students are grouped in these classrooms; they sit around tables and have laptops on them. There are projectors, smart boards and screens on the walls; also each group has their own boards. These ALCs are student-centered in their nature, students work actively and collaboratively; and the instructor guides and facilitates students' learning (Benson et. al., 2007; Beichner, Dori & Belcher, 2006; Florman, 2014) Therefore, they enable flipped instruction, hands-on activities, and collaborative learning.

This literature review aims to analyze these ALCs in terms of some aspects such as class design, technology incorporation, teaching and learning processes, and challenges. For the examination of these classrooms, an extensive research has been carried out on active learning classrooms and technology incorporated educational environments. Then, contemporary ALCs used in STEM courses have been compiled. The ALCs analyzed in this study are SCALE-UP, TEAL, TILE and Next-Gen ALC v2.0. These ALCs have been deeply investigated in terms of their physical medium, pedagogical approach, grouping and assessment procedures, teaching and learning processes, and challenges. At the end of the study a comparison between traditional classrooms and ALCs are made.

Undoubtedly, there may exist a great number of ALCs around the world and they can have significant differences from each other. This study is limited with prominent ALCs mentioned above. However, it gives a general perspective about the characteristics of ALCs, especially to use in STEM courses. Beichner, Dori & Belcher (2006) state STEM instructors should follow the contemporary approaches. This study will help STEM instructors and educational authorities to learn the characteristics of and to be aware of contemporary ALCs. It is also hoped that this study will contribute to the implementation and dissemination of ALCs.

Exemplary Active Learning Classrooms

Some of the exemplary technology incorporated contemporary ALCs successfully implemented in STEM instruction are SCALE-UP, TEAL, TILE, and Next-Gen ALC v2.0. All these classrooms are similar to each other and they have distinctive properties from the traditional classrooms in many aspects. The characteristics of these ALCs have been analyzed under several themes such as class design and technology incorporation, pedagogical approach, lectures and curriculum coverage, teaching and teaching staff, learning and students, hands-on activities and experimenting, assessment, and challenges.

Class design and technology incorporation

The main aim of these ALCs design is to engage the students in active learning. Lecture time is spent in a special technology incorporated medium (Beichner et al., 2007; Gaffney et al., 2008). Based on the enrollment, the room may involve small or large number of students (eg. 36-99, or even more) sitting on round tables. Each table accommodates 9 students in 3 groups having their own laptops with internet. There are whiteboards, multiple projectors and screens on the walls so that every student has a view (Singer, Nielsen & Schweingruber, 2012). The instructor has a symposium with interactive digital pen display, linked to projectors (Benson et. al., 2007). The students are exposed to a mixture of desktop experiments, cooperative activities, presentations, and web-based assignments. The desktop experiments and computer-aided analysis of experimental data allow the students have direct experience of various phenomena (Dori et. al., 2003). The Next Generation ALC v2.0 of Dawson College was based on providing a dedicated multi-touch interactive white board to each student group, and an asymmetrical truncated circle table design born while trying to promote peer collaboration. A "horseshoe" arrangement was developed to have larger space for activities (Charles, Whittaker & Lasry, 2014).

Pedagogical approach

Active learning is the way of instruction that rooted in constructivist and social constructivist learning theories (Charles, Whittaker & Lasry, 2014). Effective implementation of authentic learning centering upon daily life experience is the pedagogical approach of ALCs. They emphasis on learning by guided inquiry rather than sitting and listening the instructor. Team based active learning (Johnson, 1991) and in-class learning by guided inquiry (Lee, 2004) approaches are used in ALCs (Benson et. al., 2007). The ALCs help students concretize the content with the desktop laboratory experience in a media-rich classroom and use collaborative and active learning (Dori et. al., 2003). In ALCs, the teams are constituted to be heterogeneous within groups, but homogeneous across groups (Beichner, Dori & Belcher, 2006). They focus to increase student-faculty interaction and engagement (Van Horne et. al., 2014).

Lectures and curriculum coverage

In these ALCs mini-lectures are replaced with full period lectures (Benson et. al., 2008). During the class, lecture time is reduced to about 15-20 minutes (Benson et al., 2009; Oliver-Hoyo and Beichner, 2004; Perkins, 2005) at the beginning of the class period. The reduced lecture continues with group learning activities, and the students are generally more motivated than the ones in other sections (Benson et. al., 2007). Many studies support the notion that "less is more," meaning that exposing students to less information can result in better learning (Tobias, 1990; Dempster, 1993; Nelson, 2001; Fratt, 2002; D'Avanzo, 2003; cited in Perkins, 2005). The content covered is less than traditional class but the learning is greater (Perkins, 2005).

Teaching and teaching staff

ALCs have not only one instructor, but also some teaching and learning assistants. The instructor and teaching assistant(s) roam the facility and asks questions (Beichner, Dori & Belcher, 2006). Modules of the content should be relevant to daily life experience and be prepared as activities do be carried out in the classroom. The instructor assigns activities and then visits each table, engages students in conversations about their work (Beichner, Dori & Belcher, 2006). Learning assistants, upper-grade undergraduates, may serve as coaches asking leading questions, answering questions, and formatively assessing student work for the benefit of students and to inform instruction (Benson et. al., 2007).

Learning and students

ALCs have specialized active learning format that relies largely upon social interaction among students, instructor, and learning assistants (Benson et. al., 2008). In some studies, this format has resulted in an improved retention rate (Benson et. al., 2007) and it has increased the learning gains significantly (DeBeck & Demaree, 2012; Dori et. al., 2003). Student have also favored the teaching methods and the course activities and had positive comments after the course (Benson et. al., 2007). Carefully planned high engagement learning activities take place in ALCs like discovery learning and inquiry-based learning (Benson et. al., 2008), they shift learning process from a teacher-centered to a student-centered one (Beichner et al., 2007; Gaffney et al., 2008).

Hands-on activities and experimenting

In ALCs, students engage in hands-on activities and they have experience with computer simulations, work cooperatively on problems, and conduct hypothesis-driven experiments. (Singer, Nielsen & Schweingruber, 2012). They introduce a laboratory component into the courses (Dori & Belcher, 2005; Beichner, Dori & Belcher, 2006). The virtual experiment can be performed by the students (Beichner, Dori & Belcher, 2006).

Assessment

Monitoring the real time assessment of students by the teaching staff is central to these ALCs. Formative assessments are carried out during the learning activities (Benson et. al., 2008) and instructors can easily assess the conceptual understanding of students (Beichner, Dori & Belcher, 2006). Grades in the ALCs are not curved. Because collaboration is an element, it is important the class not be graded on a curve to encourage students with stronger backgrounds to help students with weaker backgrounds (Beichner, Dori & Belcher, 2006).

Some Challenges

In addition to success of the ALCs, there are some challenges regarding to shift from a traditional class to a contemporary technology incorporated active learning classes: (1) All course materials, like lecture notes, projects, exams may need a redesign (Perkins, 2005). (2) Preparation of the instructors takes lots of time and planning must be well done (Van Horne et. al., 2014; Perkins, 2005). (3) The classes are student focused; it sometimes requires giving up an uncomfortable amount of control (Perkins, 2005). (4) Planning class time to cover all the necessary topics are not easy, instructors reminds the deadline of the activities (Van Horne et. al., 2014). (5) The instructional team (instructor, teaching and learning assistants) needs extra skills. (6) A better professional development program is required for instructional team. (DeBeck & Demaree, 2012). (7) Some teaching strategies (eg. whole class discussion) may not fit ALCs (Van Horne et al., 2014). (8) Staff reluctance and lack of experienced personnel may be encountered. (9) Scarce of the financial resources may be a problem.

Active Learning Classrooms vs. Traditional Classrooms

While the ALCs analyzed in this study have similar features with each other, they distinct from traditional classroom environments significantly in many aspects. Therefore, a comparison between the ALCs and traditional classroom is needed to show their differences. Table 1 compares the characteristics of traditional classrooms with ALCs, with reference to the literature. As traditional classrooms are common and well-known, their features have not been referenced.

Table 1. Traditional classrooms versus technology incorporated active learning classrooms (ALCs)

Dimensions	Traditional Classrooms	Technology Incorporated ALCs
Physical environment	Classical classroom design enabling only instructor-student interaction	Large enrolled (Beichner et. al. 2000; Beichner & Saul, 2003; Benson et. al., 2007; Rogers et. al., 2015), comfortable (Beichner & Saul, 2003), round tables with nametags (Gaffney et. al., 2008), interactive environment (Van Horne et. al., 2012; Florman, 2014) visualized (Beichner,1999; Dori et. al., 2003)
Lectures	Lecturing through the 50-90 minute classes	Lecturing reduced to about 10-20 minutes (Benson et al., 2009; Oliver-Hoyo & Beichner, 2004; Perkins, 2005)
Technology incorporation	Supportive tools like smart boards, projectors etc.	Ultimate level of technology incorporation (team or student laptops, instructors station, projectors, video and document cameras, TVs, clickers, software, etc.)(Beichner at. al., 2000; Oliver-Hoyo & Beichner, 2004)
Activities	Individual and group activities, question-answer, problem solving	Out-of-class readings, group discussions, hands-on activities, internet search, Socratic dialogues (Beichner, Dori & Belcher, 2006; Benson et.al., 2007)

Laboratory activities	Separate laboratory hours, individual or group works in lab.	Laboratory works integrated to the lectures (Gaffney et. al., 2008; Perkins, 2005), team work (Beichner, 1999)
Curriculum coverage	More topics can be covered	Essential topics can be covered in great depth (Perkins, 2005)
Grouping	Rare or none	Students work in groups (Gaffney et al., 2008).
Responsibility	Teachers are responsible for students' learning	Students take learning responsibility (Beichner et. al., 2000; Gaffney et al., 2008)
Instruction	Teacher – centered	Minimized lecturing, peer instructions, student-centered (Benson et al., 2007)
Learning	Passive learning	Active learning (Beichner, 1999), peer review, critique (Perkins, 2005), research environment (Kohl & Kuo, 2012), team based (Benson et al., 2007), group learning activities (Gottfried et. al., 2007), inquiry learning (Oliver-Hoyo & Beichner, 2004), collaborative learning (DeBeck & Demaree, 2012),
Instructor	Lecturer, authoritarian, active through the class	Mentor, acts as learning guides, provides materials (Perkins, 2005), assigns activities, walks from table to table, engages students (Beichner, Dori & Belcher, 2006)
Teaching assistant	Separate lab or recitation role	Roam the facility, asks questions (Beichner, Dori & Belcher, 2006), provides materials (aid instructor) (Perkins, 2005)
Learning assistant	No LA	Serves as coach, answers questions, asks leading questions, and formatively assesses student work (Benson et al., 2007)
Student	Passive learner, no interactions with peers, motivation is difficult	Active learner, group member (Perkins, 2005), generally more motivated (Benson et al., 2007)
Assessment	Classical exams: quizzes, mid-term exams, final exam	Formative assessment, real time assessment (Benson et al., 2008)
Basic challenges	Teacher-centered, generally monotony medium, boring for students	No lecture notes (Beichner et al., 2000), preparation of instructors takes lots of time, planning must be well done, sometimes uncomfortable amount of control (Perkins, 2005), classroom management needs extra qualification, the efficacy is limited by the skill of the instructional team, professional development program is desired (DeBeck & Demaree, 2012).
Benefits	Economic space, no need for extra qualifications for the staff	Team work ability (Beichner & Saul, 2003), higher cognitive skills (Oliver-Hoyo & Beichner, 2004), communication skills (Erol, Özcan & Luft, 2016), critical thinking (Beichner, 1999), scientist students (Handelsman et al., 2004), presentation skills (Beichner et al., 2000)

CONCLUSION

In the last years, an extensive change has been occurring regarding to educational environments. This change is seen especially in STEM courses with the emergence of approaches like active learning, collaborative learning, flipped instruction, etc. Therefore, educational authorities, teacher trainers and STEM instructors must be aware of these approaches and classrooms.

Technology incorporated contemporary ALCs held in this study are technology-rich environments that may be large-enrolled and enable a great number of students become active at the same time. These ALCs adopt a constructivist approach and students have daily life experiences by doing experiments, research and hands-on activities. Lecture in the ALCs is generally minimized; however they result in better student performance and more learning. There may be more than one staff (the instructor) in these ALCs such as teaching and learning assistants. They do not teach; rather, they guide students' activities and facilitate their learning. Formative assessment takes place in ALCs and students' collaboration and engagement in activities and group works have also importance for grading. Compared to traditional classrooms, ALCs have been proved to yield better results in terms of learning, retention and affective dimensions.

Besides the advantages above, ALCs have some challenges. It may be hard for both instructors and students to adopt an ALC who are accustomed to traditional learning environment. Although they are student-centered and may seem easy to handle for instructors, they require substantial time and effort to prepare for the courses and to instruct them. Moreover, curricular and instructional materials should be adopted for these ALCs, and they will need more financial resource.

In order to overcome the challenges, teacher education programs should be revised and in-service training activities should be carried out. Additionally, the authorities should invest in comfortable classrooms and contemporary technological tools. Also, continuous faculty encouragement programs should be an academic culture to introduce and use ALCs.

STEM instructors may use the ALCs analyzed in this study. They may also be suitable for other courses rather than STEM with minor changes, even for social sciences. Change may be a challenging and slow process, especially for the ones who are accustomed to traditional; however, it is a prerequisite in this age where rapid changes are emerging. When the educational stakeholders take a decision for change, the success will likely to come.

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