Classroom Layouts for Technology-based Active Learning Spaces

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Abstract—Are the traditional straight-row-of-desks classrooms suitable for actual active learning pedagogies? If not, how shall they be? This project aims to answer these two questions and, in this first step, surveys existent active learning spaces. It starts with the seminal SCALE-UP, followed by TEAL, PAIR-up, and TILE projects. These layouts generally encompass round tables with nine seats, moving tables and chairs, 360º wall-covered whiteboards, and an equal assortment of projectors/monitors so every student sees the information. Other exemplary cases are addressed, for instance, McGill University's principles for designing rooms for active learning. Although it is not an active learning space, a recent ground-breaking proposal is addressed: "teaching in the round". Concluding, flexibility is the keyword in actual learning spaces. Rooms must mutate into different configurations according to the type of class. However, tables should be round and equipped with utilities for students' work.

Keywords - active learning spaces, classroom layout, educational technology

I. INTRODUCTION

Active learning is rooted in constructivist theory and focused on student-centered, collaborative learning [1, 2]. It gained momentum in the last twenty years of century XX, to which Bonwell and Eison's report significantly contributed [3]. In addition, the Bologna Process, which developed in the early years of century XXI, contributed to its dissemination in Europe. Nowadays, a simple internet search reveals that active learning is worldwide spread.

The Bologna Process relied on active learning, aiming for students to acquire transferable competencies that the job market was asking for and that traditional lecturing was not delivering. This strategy was accompanied in Japan [4]. One question, however, arises: what is? What characterizes it?

What is active learning? Simply put [3], active learning involves "students in doing things and thinking about the things they are doing" (p. iii). The distance from traditional lecturing starts to become evident due to the emphasis on thinking, while lecturing is more assimilating (whether thinking or not). Higher-order cognitive processes, such as analyzing, evaluating, and creating, must be presented in students' activities [5, 6]. Active learning characterization helps in defining the picture [3]:

- students are involved in more than passive listening;
- students are engaged in activities (e.g., reading, discussing, writing);
- there is less emphasis placed on information transmission and greater emphasis placed on developing student skills;
- there is greater emphasis placed on the exploration of attitudes and values;
- student motivation is increased (especially for adult learners);
- students can receive immediate feedback from their instructor;
- students are involved in higher-order thinking (analysis, synthesis, evaluation).

Nonetheless, it was found that scholars do not understand well or apply active learning appropriately, having a superficial approach to the concept, limited to the strict application of a project or solving a problem in the classes [4], which is manifestly reductive if the objective is students' acquisition of transferable competences.

Active learning has its merits, mainly in keeping students engaged in their learning work and complementing their technical competencies with transferable skills. By the end of the learning path, students are better equipped and ready for jobs. Active learning, however, has hurdles, some extrinsic, some intrinsic. Among the extrinsic difficulties, which are heavily centered on the teacher, one may find [3]:

- "the powerful influence of educational tradition;
- faculty self-perceptions and self-definition of roles;
- the discomfort and anxiety that change creates;
- the limited incentives for faculty to change."

while the intrinsic are (p. v):

- "the difficulty in adequately covering the assigned course content in the limited class time available;
- a possible increase in the amount of preparation time;
- the difficulty of using active learning in large classes;
- a lack of needed materials, equipment, or resources."

Although this scenario, another under looked question emerges: does active learning work in rooms designed for traditional lecturing? Which prompts a subsequent question: if not, what should be active learning spaces' desirable layout, acknowledging the high involvement of educational technology nowadays, especially in higher education?

This article starts by summing up the traditional lecturing classrooms, the given view, and then surveys room layouts purposefully designed for technology-based active learning, all in the present century.

II. THE GIVEN VIEW

Traditional classrooms were designed to follow the traditional teaching method: lecturing, or exposition. The communication follows a one-sense flow from the lecturer to the students. The lecturer's speech, what he writes on the whiteboard, projected slides and videos, and teaching information stream from the front of the room towards students (Fig. 1). Eventually, students may answer questions prompted by the lecturer. Therefore, the traditional classroom layout has straight rows of desks where the receivers sit, facing the front of the classroom, where the lecturer lays, together with the whiteboard, and video projector, i.e., the transmitters. The lecturer may walk around the aisles, ensuring that all students are attentive. In the teaching-learning system, teaching dominates. Students learn individually. Thus, their attention is of paramount importance. The straight row of desks limits turning heads, side conversations, and other kinds of distractions which could disturb students' assimilation. At least since the 19th century, this has been the given view of a classroom layout.

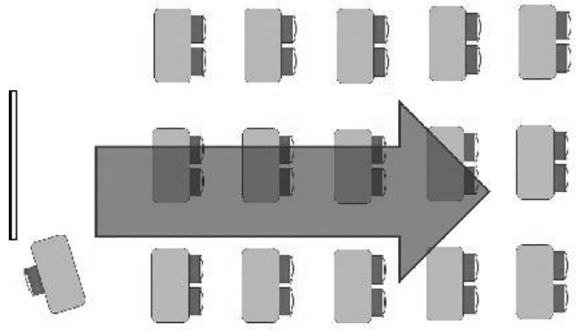

Fig. 1 Traditional classroom layout composed of rows of desks, where the students sit, facing the front of the room where the lecturer, whiteboard, and video projector is.

The test of time has come to sanction the traditional layout as effective (otherwise, it would probably have already been changed). Although it should be the nature of the task that must direct the classroom arrangement, Wannarka and Ruhl [7] conclude that "students display higher levels of appropriate behaviour during individual tasks when they are seated in rows" (p. 89) when compared to sit in groups or semi-circles. Appropriate behaviour means "following teacher's directions (speaking only with permission, keeping hands to self, etc.) and attending to academic tasks".

III. ACTIVE LEARNING CLASSROOMS LAYOUTS

Traditionally, only gifted students could attend higher education. Does this profile still hold nowadays? Do the highly demanding jobs in post-higher education training accommodate individually brilliant students? The trend of higher education democratization and the demands of the job markets have challenged the traditional lecturing process and called for new ways to make students learn (the focus changed from teaching to learning). As a result, active learning pedagogies have also entered the higher education ecosystem. However, active learning differs from traditional expositive lecturing and demands appropriate spaces. Costa, et al. [8] summarize the two approaches distinctions in Table I.

Table I. Differences between the traditional classroom and the active learning room, according to costa, et al. [8].

Feature	***Traditional Classroom***	***Active Learning Room***
Teacher's positioning in the room	Usually in the forefront of the room because it centers attention	Undefined positioning, which invites the teacher to walk around the room and interact with students to support teaching activities
Desks	Limited reconfiguration flexibility, which makes teamwork difficult	Students sit around the tables, which favours teamwork
Projection display	One single screen under control and usually accessible only by the teacher	Variable number of screens (from none to one per group of students) accessible to teachers and students
Whiteboards	Whiteboards at the front of the room, writing materials with the teacher	Writing boards scattered around the room walls or with wheels, autonomous use by students
Noise	Considered a disruptive element in the class	Natural, it is a consequence of the students' interaction and involvement
Mobility	Non-existent; students sit at fixed desks, and the teacher with little space to move around	Stimulated; stimulated by the type of furniture (e.g., wheelchairs) and the availability and spatial distribution of pedagogical resources

In the technological era, where advances in smart devices dominate higher education students, redesigning classroom spaces has been advocated to contribute to more active learning and increase student involvement [9].

Technology creates opportunities, accelerating students' learning and preparing them for a professional life within companies. Five factors encourage the technological trend [10]:

- generation Z is already acquainted with using technology and, for this reason, expects to take advantage of it in higher education classrooms and projects;
- technology generates opportunities and effectiveness at work;
- most students, teachers and parents want higher education with a meaningful approach;
- scientific studies are discovering how learning can take place more effectively;
- flexibility in sharing and accessing content are requirements of the nowadays students.

The demand to innovate on classrooms stems from the need to share knowledge among everyone. This vision dominates several factors, from better-placed desks and chairs, new collaborative software and "students who practised self-directed learning more easily adapted online. And transparent, meaningful, and open channels of communication between schools, students, teachers and parents were incredibly important" [11]. COVID-19 and emergency remote teaching introduced irreversible changes, which may not be ignored.

Some higher education institutions have been devoting research aiming to identify and test the most suitable classroom layouts for active learning pedagogies, which are detailed in the following sections.

A. SCALE-UP

SCALE-UP, firstly, Student-Centered Activities for Large-Enrollment University Physics [12], then Student-Centered Activities for Large Enrollment Undergraduate Programs [1], and, more recently, Student-Centered Active Learning Environment with Upside-Down Pedagogies [13], was a pioneering project, developed at the end of century XX, to design a classroom for active and collaborative learning, aiming to increase STEM students' success. The room was designed to improve student interaction while they work on assignments. The lecturer freely observes, asks questions, and clarifies misgivings while circulating through the classroom. In the project's phase II, according to the layout of a SCALE-UP room, students are allocated by threeelement groups at round tables (180 cm diameter) with nine seats to discuss their work (cf. Fig. 2). In addition, some whiteboards are arranged so the group can draw schemes and align their thinking. The instructor station was firstly on a rolling cart. Considering technology, each group has one laptop computer to search on the internet and projectors.

SCALE-UP rooms had the novelty of being classrooms without a defined front [14]. Besides North Carolina State University, many more universities worldwide adopted the SCALE-UP room configuration for active learning purposes, sometimes adding small changes [1, 13].

B. TEAL

TEAL stands for Technology-Enabled Active Learning. It was implemented at MIT by the beginning of century XX and grounds on the SCALE-UP project, encompassing policentrically designed rooms with round tables for student work. There are 13 in the room. The TEAL room adds technology to the SCALE-UP room, providing a "media-rich environment, " including videos with 2D and 3D visualizations, desktop experiences, web-based home assignments, and conceptual questions using PRS, personal response system [15].

C. PAIR-up

Grounded on the SCALE-UP and the TEAL active learning classrooms layouts, by the end of the first decade of century XXI, the University of Minnesota has built pilot rooms based on the PAIR-up model (Pedagogy-rich; Assess learning impact; Integrate innovations; Revisit emerging technologies). The PAIR-up rooms have two main girders: 1) space flexibility, i.e. the room should transform into different configurations, and 2) student-centered teaching because the ultimate objective is to improve students' learning [16, 17]. The first two rooms had 45 for Electrical Engineering/Computer Science (Fig. 4) and 117 seats for Biological Sciences. The tables have nine seats for three student groups teamwork. These are laptop-based rooms, and there are 360º glass marker boards.

PAIR-up rooms provide flexible active learning rooms. There are demountable wall systems, which allow for flexing the room according to the needs. In addition, the ALCs employ reconfigurable low-profile flooring with internal power and cable management to accommodate reconfiguring technology and wiring in the room (cf. Fig. 4 and Fig.5).

Fig. 2 SCALE-UP room at the North Carolina State University; 99 seats.

Fig. 3 An example of a TEAL room at MIT, including the nine-seat tables, 360º whiteboards and video projectors; the desktop experiments are visible in the foreground. Photo from [15].

Fig. 4 PAIR-up room at the University of Minnesota. Photo from [17].

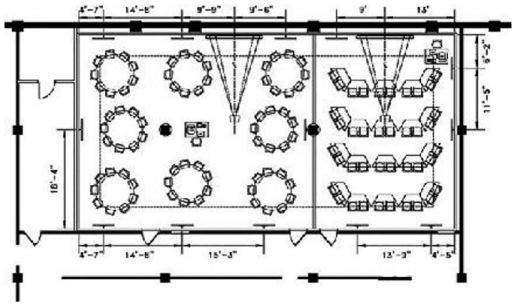

Fig. 5 The PAIR-up room is flexible. Demountable walls and wheeled furniture are crucial for swift layout changes. Schema from [17].

D. TILE

TILE (Transform, Interact, Learn, Engage) is an approach to teaching that incorporates inquiry-driven, team-based learning to increase teacher and student engagement. TILE instructors gain an understanding of these pedagogies through well-designed workshops, one-on-one consultations, and focused technology training. This professional development support enables instructors to create and deliver courses best suited to the learning needs of students in TILE classrooms.

TILE rooms were implemented by the University of Iowa around 2010 and ground on the SCALE-UP and TEAL projects, encompassing the nine-seat tables, power sockets and network access [18]. Each table has three laptops. As depicted in Fig. 6, the walls have multiple whiteboards which cover 360º. Each table has three networked laptops and its own dedicated wall-mounted monitor that can display data from a laptop on the table, the instructor's screen, or work from other laptops around the room (cf. Fig. 6). The instructor's station is in the centre of the room.

Fig. 6 Detail of a table in a TILE room, remarking one laptop per group of three students. Photo from [18].

E. WSU's G10 Room

In the building The Spark, Washington State University has three classrooms specifically designed for active learning classes. One is the G10 room with 126 seats (Fig. 7). Each table has six places. Students sit in a U-shape around the table, i.e., they occupy three sides of the rectangular tables, so everyone sees others' faces. The free side has a large flat panel and a PC. Connecting personal laptops to project in the flat panel is also possible. To improve flexibility in the space, the chairs are wheeled, and the alleys are spacious for circulation. Nonetheless, the tables are fixed. The room also encompasses two projectors with large screens for all classroom visibility.

Fig. 7 Washington State University's Spark G10 active learning classroom. Students view. Photo from [19].

F. McGill's "Principles for Designing Teaching and Learning Spaces"

Around one decade ago, McGill University established its "Principles for Designing Teaching and Learning Spaces" [20]. It is worth sharing the five principles in full:

1. academic challenge: learning spaces should allow students to actively engage with content and include a range of technologies that support multiple modes of teaching and learning;
2. learning with peers: learning spaces should provide features that permit students to work both individually and in collaboration with one another;
3. experiences with faculty: learning spaces should facilitate communication and interaction between students and faculty;
4. campus environment: learning spaces should be consistent with the university's culture and priorities as reflected in the campus master plan, follow university design standards, and be designed with future flexibility in mind;
5. high-impact practices (HIPs): learning spaces exist within a larger campus context; there should be an ease of transition between spaces so as to better support highimpact practices inside and outside the classroom.

These principles intersect with five dimensions for proper operationalization: layout, furniture, technologies, acoustic, and lighting/color. They are detailed in full in Table 2.

TEAL inspired McGill's active learning rooms. Fig. 8 depicts an exemplary room, McIntyre 325 [21]. The tables have eight seats for individual or group work. There is plenty of space for working materials and laptops, and the armless chairs are wheeled, which allows multiple configurations. The instructor's desk is at the center of the room. Sightlines are not obstructed, and circulation and moving around the tables is easy. All tables have microphones and power outlets. One wall has a large whiteboard.

Table II. McGill's "Principles for designing teaching and learning spaces" (partial) [20].

	Layout	***Furniture***	***Technologies***	***Acoustics***	***Lighting/Color***
Academic challenge: promote individual, active engagement with content	Work surfaces for notebooks, laptops, and textbooks.	Comfortable furniture. Varied furniture to support different types of tasks and preferences.	Access to infrastructure (e.g., printing, power for student laptops). Access to resources (e.g., LMS, internet, virtual labs, specialized software). Multiple sources and screens for simultaneous display of different learning materials	Acoustic design to avoid distraction from outside and inside sources.	Appropriate lighting forindividual work. Intentional use of colour to promote focus.
Learning with peers: promote active engagement with one another	Promote face-to-face communication (e.g., two rows of students on a tier, small groups). Individuals can move about easily. Unobstructed sightlines	Flexible seating(e.g., fixed chairs that rotate, movable tables and chairs, tablet chairs on wheels). Intentional use of furniture of different heights and shapes.	Shared workspaces (e.g., writable walls, digital workspace).	Sound zones support multiple simultaneous conversations. Appropriate amplification available (e.g., student table microphones).	Different lighting patterns to support different activities. Using colour to define groups' use of space.
Experiences with faculty: promote interaction and communication	Easy access to all students (e.g., multiple aisles, unobstructed sightlines).	The podium does not interfere with sightlines, movement and interaction while being large enough for instructional materials. Flexible furniture to support different teaching strategies (e.g., movable, variable heights).	Screen sharing. Ability to control classroom technologies away from the podium (e.g., remote mouse, wireless projection).	Sound zones support multiple simultaneous conversations. Appropriate amplification available (e.g., wireless audio amplification).	Different lighting patterns to support multiple types of teaching tasks. Colours distinguish purposes (e.g., where chairs go, what groups work on what surfaces/ with whom).

Fig. 8 Active learning purposefully designed classroom at McGill University. The McIntyre 325. Photo from [21].

G. "Teaching in the Round" by David Harlan

David Harlan, an academic on theatre, shows, in a workshop, delivered at Washington State University, how a rounded classroom should be managed [22]. The appositeness of the workshop is that David Harlan delivers it in the proper rounded room, staging evidence of its pros and revealing the necessary mastery that the instructor must hold during his performance.

The room is composed of a central circular open space, like an arena, where the presenter moves, a mobile lectern, and fixed tables and seats arranged in circles around the central space, as depicted in Fig. 9. Such architecture contributes to the conversion of a traditional lecture into a theater play.

Fig. 9 Washington State University's Spark G45 rounded room. Main view from the floor. Photo from [23].

The presenter must keep the audience attentive and engaged all the time. The rounded room is designed for such purposes, but some tactics and warnings disclosed by David Harlan are required to accomplish the objectives effectively. Therefore, some previous staging work is required. Besides their scientific and technical abilities, the teacher must sum theatrical skills. In summary:

- field-of-view: this is the first concern raised by the particular room design; the presenter always has someone at his back; the solution is movement;
- motion: the arena should be divided into quarters; the quarters help the presenter organize their moving (round stages have no corners!); the lecturer should split their time among the quarters and should not repeat the same moving patterns during the talk; diversity is the key to an engaging talk; moving must be coordinated with the presentation; the presenter should not move when is presenting an idea or concept but move when he changes to another idea or concept;
- positioning and lighting: keep in the circle and avoid walking in the aisles because the lighting is designed to focus inside the circle; the remaining space, aisles and seats, are in the penumbra and it is difficult to see the lecturer's face (which should be avoided); the exception is when the lecturer wants to give "the stage" to students (e.g. because they are discussing lively); in such cases "disappear" into the aisle darkness;
- eyes focus: expand the circle of attention; do not focus on the front only; extend attention to other senses besides vision; hearing is 360º and may help to understand if the audience behind is engaged or not; this way, the presenter may feel that someone is drifting away, and, at that point, he may redirect the focus to that person and hook him into the presentation again (which is common in traditional rooms, but here it is 360º);
- interactions: during questions and answers with the audience, approach the person who posed the questions, and then move away in the opposite direction in the circle repeating the question (for the micro and recording if that is the case); in the opposite point turn again to the questioner; thus, the lecturer has most of the audience again in front of him, and the focus still is the questioner and his questions; in this way, the lecturer has created an atmosphere for discussion encompassing most of the audience; if many questions happen at the same time, or if the attendants start discussing each other, the lecturer let it flow and intervene to moderate the excesses; if that is not desirable, select the questioners and speak to one at a time, breaking the dispute.

Typical comments from the attendees:

- sense of proximity;
- permanent movement around;
- gestures;
- evokes imagination.

The round room is a suitable space for discussions, debates, and performances. Even expositive lectures may gain improved liveliness as long as they are adequately rehearsed.

IV. CONCLUSION

Flexibility is the keyword that emerges. Furniture must be movable, mainly chairs, allowing different layout configurations. This is possible only in a spacious room, as students and faculty must circulate freely.

The tables must be round so everyone can see each other and seat around nine students. It should provide power sockets, cable internet access, and ample space for work-

ing materials and laptops. An interesting aspect of this quartercentury survey is that personal laptops substituted desktop computers.

The instructor's desk should be placed in the center of the room, minimizing the distance to the students. Sightlines must not be obstructed.

Walls also have roles. Either large glass whiteboards or projection screens usually occupy them. Thus, the room arrangement must ensure the sightlines are clear.

The detailed analysis of these projects, proof-of-concept, and examples permits the identification of good practices on acoustics, lighting, and suitable technology to support students' work and learning. In addition, the consideration of McGill University's principles is a must.

For future improvement, maybe bring the idea of the central arena in the round room to the active learning spaces, increasing their flexibility and allowing more performative lectures.

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