Chapter 3
Active Learning Classrooms (ALCs)

D. Christopher Brooks

Glossary of Acronyms

ALC	Active Learning Classroom
LCD	Liquid-crystal display
MIT	Massachusetts Institute of Technology
SCALE-UP	Student-Centered Activities for Large Enrollment Undergraduate Programs
TBL	Team-Based Learning
TEAL	Technology Enabled Active Learning
TILE	Transform, Interact, Learn, Engage

3.1 Introduction

Two decades after Robert Beichner, a professor at North Carolina State University, built the first technology-enhanced classroom designed for collaborative, studio-based learning, the experimental formal learning spaces that have come to be known as *active learning classrooms* (ALCs) are on the cusp of becoming a learning space staple at colleges and universities (Beichner, 2014). In fact, active learning classrooms are the overall number one strategic technology for higher education in 2017 and are expected to achieve mainstream adoption (deployed in 61–80% of institutions) in the next 5 years (Grajek, 2017). The spread and popularity of active learning classrooms from the United States to Oceania, Europe, and Asia in recent years have been fueled, in part, by empirical evidence that demonstrates clearly the impact of learning spaces on students' learning outcomes and instructors' teaching practices.

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This review of the literature and presentation of cases of active learning classroom use are the most comprehensive coverage on the subject to date and include only the best pieces of research published around the world on the subject. Specifically, this review includes literature related to assessing the impact of ALCs on student learning outcomes, evaluations of the layouts and furniture of learning spaces, the experiences of students and instructors, and a brief consideration of research on informal learning spaces (nonclassroom spaces).

3.2 Formal Learning Spaces

The revolution in learning spaces higher education has been experiencing for the last two decades is in many ways a response to a paradigm shift in higher education pedagogy from more passive to more active forms of learning. Popularized by Bonwell and Eison (1991), active learning is explicitly student-centered and involves "anything that involves students in doing things and thinking about the things they are doing" (p. 2). Active learning stands in opposition to instructor-centered, passive forms of learning (e.g., listening to lectures) that have dominated the higher education classroom for centuries. Beyond the focus on the student, one of the appeals of active learning is the plurality of activities that can be employed in its service, including the following:

- Class discussion,
- Small group discussion,
- Collaborative group work,
- Team-based learning (TBL),
- Think-pair-share,
- Short, in-class writing exercises,
- Student debate,
- Reactions to media (e.g., video, audio),
- Exercises with manipulables (e.g., Legos, circuits, etc.),
- Gamification of content,
- Poster sessions or gallery walks (i.e., sharing group work with other groups),
- Group quizzes, and
- Learning by teaching.

The other major appeal of active learning is that it has repeatedly been demonstrated to be a superior approach to lecturing in terms of both improving student learning and decreasing failure rates (Hake, 1998; Prince, 2004; Hoellwarth & Moelter, 2011; Freeman et al., 2014).

The major limitation confronting instructors who abandoned the lecture for active learning, however, was that the spaces in which they were teaching their courses were not conducive to activities other than listening to lectures. Traditional classrooms were designed and built with the assumption that lecture would be the primary mode of instruction with a clearly designated front of the classroom denoted by a

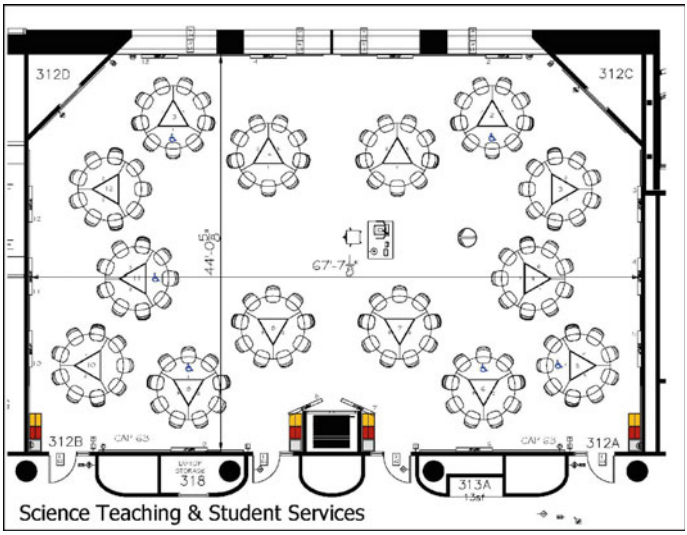

Fig. 3.1 Active learning classroom (ALC) at the University of Minnesota (*Source* www.flexspace.org)

combination of chalk or marker boards, a podium, lectern, or desk, and/or elevated platform or stage. And while it is possible for active learning to occur is such a space, one might expect that formal learning spaces designed with active learning activities in mind would be a more favorable environment for deepening student engagement.

Indeed, these were the expectations that Beichner held when he developed the very first ALCs as part of the Student-Centered Activities for Large Enrollment Undergraduate Programs (SCALE-UP) project. The SCALE-UP classrooms were designed to transform the way in which large introductory physics courses were taught by including the round tables for student seating, laptop connectivity, and easy access to lab equipment that would become the basis for future versions of ALCs (Beichner et al., 2007). Building on the basic design of the SCALE-UP classrooms, the Massachusetts Institute of Technology (MIT) (USA) incorporated more technology to allow instructors to incorporate more computer-based simulations and visualizations into their classroom activities (Dori & Belcher, 2005). The University of Minnesota (USA) borrowed heavily from both the SCALE-UP and TEAL models to develop the first technology-enhanced classrooms formally referred to as ALCs (Whiteside, Brooks, & Walker, 2010). The Minnesota model focused heavily on the integration of digital technologies with furniture design and layout to produce several ALCs of various sizes (see Figs. 3.1 and 3.2). Around the same time, the University of Iowa also developed their versions of ALCs known as Transform, Interact, Learn, Engage (TILE) spaces and was the first to develop a faculty development program centered on training faculty how to redesign their courses to fit in these spaces (Van Horne et al., 2014).

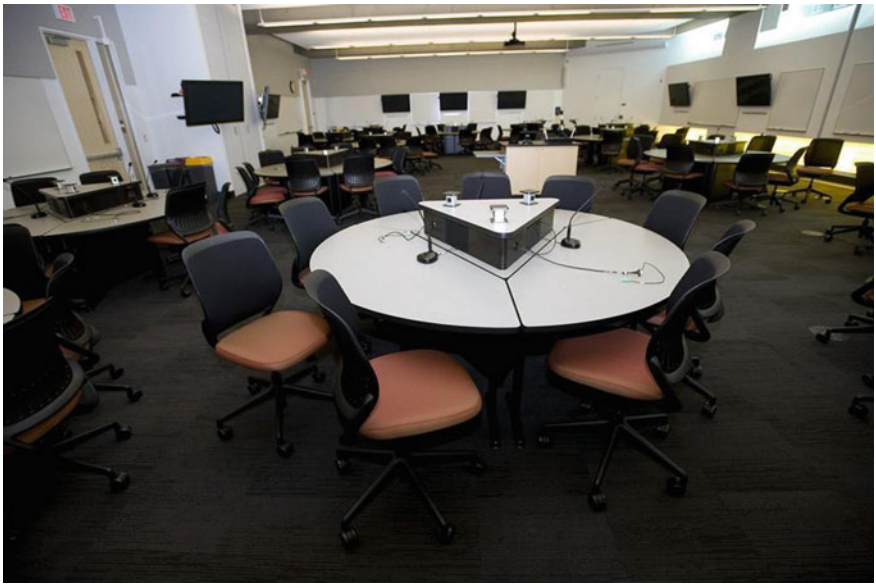

Fig. 3.2 Active learning classroom (ALC) at the University of Minnesota (*Source* www.flexspace.org)

In more recent years, colleges and universities all over the United States, Australia, Europe, and, more recently, Asia have either borrowed directly from these ALC pioneers or have been working to develop their own versions of ALCs. Even when there are significant departures from the original models of ALCs, these innovative classrooms "typically feature round or curved tables with moveable seating that allow students to each other and thus support small group work. The tables are often paired with their own whiteboards for brainstorming and diagramming. Many tables are linked to large liquid-crystal displays (LCDs) so students can project their computer screens to the group, and the instructor can choose a table's work to share with the entire class. Wireless Internet plays an important role in retrieving resources and linking to content management systems, and depending upon the size of the room, table microphones can be critical to that every student's voice can be broadcast across the room" (Baepler, Walker, Brooks, Saichaie, & Petersen, 2016, p. 10). Given restrictions that institutions face in terms of costs, infrastructure, and goals, there persists considerable variation in the levels and combinations of low and high technology in ALCs. Regardless of the form, the functional intent of creating a formal learning environment conducive to active learning pedagogies and activities remains largely the same.

3.3 Assessment of Impact

Higher education is bombarded constantly by new applications, new devices, new platforms, and other educational technologies that promise to revolutionize teaching and learning as we know it. Often times, these technologies are purchased, adopted, and/or implemented without any systematic empirical evidence that demonstrates clear benefits either teaching or learning, much less both. Fortunately, ALCs are the one educational technology for which considerable evidence supporting their efficacy for both instructors and students has been produced.

3.3.1 North Carolina State University and MIT

The first evidence that ALCs might have a positive impact on the student experience was produced by a team of researchers from North Carolina State who studied the SCALE-UP classrooms for about 4 years. They found that students who took courses in the experimental classrooms outperformed their peers who took the same course in traditional classrooms and noted that students in the SCALE-UP classrooms reported higher levels of satisfaction and confidence and that underrepresented groups more likely persist in STEM courses (Beichner et al., 1999). In a later study, Beichner and his colleagues analyzed data collected from over 16,000 students across over two-dozen institutions and found that the SCALE-UP classrooms and curriculum have a positive and significant impact on an array of outcomes including attitudes, attendance rates, problem-solving skills, and conceptual understanding (Beichner et al., 2007). Researchers at MIT similarly found that TEAL classrooms and the new curriculum for which they were designed were associated with higher levels of conceptual understanding and lower failure rates than were traditional classrooms and lecture-based approaches (Dori & Belcher, 2005). Despite the groundbreaking efforts of the North Carolina State and MIT researchers to transform formal learning spaces, their early research was limited by a lack of controls in the research design, making it impossible to discern whether or not the observed effects were due to the pedagogy or the learning environment.

3.3.2 University of Minnesota

Researchers at the University of Minnesota used a quasi-experimental design in which the instructor, course, class materials, exams and other assessments, assignments, pedagogical approach, and even the time of day were held constant. Post hoc equivalency tests also established that the students in the courses were similar in every way excepting aptitude. The Minnesota researchers found that students in the ALC reported significantly higher levels of engagement, enrichment, flexibility,

and course/room fit than their peers in the traditional classroom (Whiteside et al. 2010). Students in the ALCs were also able to overcome deficiencies in aptitude (as measured by a standardized college entry exam) to earn the same grade as their classmates in the traditional space (Brooks, 2011). In a follow-up study under nearly identical conditions, the Minnesota researchers were able to replicate their original findings, solidifying the empirical evidence about the impact of learning spaces on student experiences and learning outcomes (Cotner, Loper, Walker, & Brooks, 2013). Using data derived from classroom observations conducted during the first round of research, the Minnesota researchers also found that the spaces shaped the way the instructor behaved and taught the course, which, in turn, shaped the observed on-task behavior of his students (Brooks, 2012). In summary, ALCs have an independent and significantly positive effect on both teaching practices and learning outcomes.

Beyond the independent effects of ALCs on student learning outcomes, researchers at the University of Minnesota advanced our understanding of importance of the interaction between space and pedagogy in three important ways. First, they found that when an instructor intentionally transforms her course from one that is primarily delivered via lecture to one in which active learning in an ALC is the dominant modality, student learning gains are significantly larger for learners of all abilities (Brooks & Solheim, 2014). In addition to suggesting that instructors should adjust their pedagogical approach to fit the learning environment in which they are delivering the course, this line of research also suggests that lecturing in an ALC might actually limit student learning.

Second, in another longitudinal, quasi-experimental design, researchers tested for the effects of an instructor transforming a lecture-based course held in a large fixed-seat auditorium into an active learning course held in a much smaller ALC by reducing the face-to-face time by two-thirds (e.g., instead of all students meeting three times per week, students were divided into three groups each of which met only one time per week). They found that students achieved learning outcomes (as measured by a standardized exam) that were "at least as good, and in one comparison significantly better than, those in a traditional classroom" (Baepler, Walker, & Driessen, 2014). Such a finding challenges seriously the traditional notions of the meaning of a "credit hour" and the importance of the amount (as opposed to the quality) of contact hours between an instructor and students.

Third, ALCs fundamentally change the network of social relationships that constitute a "social context" along four dimensions: student–student general relations, student–instructor formal relations, student–instructor informal relations, and student as instructor. Student scores on each of these four dimensions have been found to be significantly larger for students in ALCs than for students in traditional classrooms. Moreover, these different dimensions predict student learning outcomes as measured by grades differently with student as instructor and student–instructor formal relations predicting significantly higher grades, student–student general relations predicting significantly lower grades, and student–instructor informal relations having no effect (Baepler et al., 2016, p. 38–51).

3.3.3 Emerging Research

Researchers at several other institutions have been conducting their own research to investigate the impact of ALCs on student learning outcomes. At the University of Minnesota-Rochester, Muthyala and Wei (2013) executed a quasi-experimental project comparing two different types of ALCs and found no significant difference in student learning outcomes, suggesting that a variety of different types of ALCs can produce similar results. Ridenour, Feldman, Teodorescu, Medsker, and Benmouna, (2013) found preliminary evidence that students working in an ALC environment using active learning techniques improve their problem-solving abilities. McArthur (2015) found that the interaction between instructors and the physical space of the learning environment impacts students' behavioral, cognitive, and affective learning outcomes, providing additional evidence that instructors should adapt teaching approaches based on classroom affordances and limitations. In another quasi-experimental project at Bethel University (USA) that compared a low- and high-tech version of an ALC, researchers found no significant differences between the two types of spaces and that student collaboration and collaborative writing surfaces were more important than digital technologies (Soneral & Wyse, 2017).

3.4 Empirical Evaluations

In addition to systematic assessments of the impact of ALCs on student learning outcomes, many researchers have been engaged in the processes of evaluating aspects of the physical learning environments and aspects of the student and faculty classroom experience.

3.4.1 Physical Learning Environments

Although student evaluations of the spaces in which they take their courses are no substitute for rigorous empirical research that ties spaces to student learning outcomes, they are important in helping us understand students' environmental, furniture, and layout preferences in new learning environments. Another group of researchers at the University of Minnesota sought to understand the relationship between formal learning environments and students' evaluation of the quality of the environments, perceived learning, and course satisfaction. They found that students' evaluations of the quality of their learning environments (e.g., temperature, air quality, acoustics, lighting, furniture, technology, etc.) were positively associated with students' self-reported experiences (Choi, Guerin, Kim, Brigham, & Bauer, 2013–2014).

Researchers at St. Olaf College (USA) evaluated the furniture layouts of three experimental learning spaces in a new science and math building to understand

student and faculty preferences. They found that faculty preferred a furniture layout that maximized flexibility for both active learning and lecture-based pedagogical approaches. Students, on the other hand, had learning preferences that were activity dependent. For lecture-based courses, students preferred rows of tables; for active learning or mixed pedagogy courses, students preferred the same flexible classrooms preferred by instructors (Walczak & Van Wylen, 2013–14).

When Lethbridge College (Canada) expanded its ALC capacity, researchers have students and faculty evaluate new furniture and technologies included in the new designs. Among the key findings related to students include the following:

- Students in different courses require different amounts of workspace;
- Students preferred sitting near one another at round tables to collaborate; and
- Students utilized mobile charging stations when provided.

Faculty reported experiences similar to those of students:

- Instructors did not find ALCs conducive to in-class assessments;
- Instructors needed more technical and pedagogical training to learn how to use the ALC more effectively;
- Instructors found ALCs to be more flexible compared to traditional classrooms; and
- Instructors found ALCs to be more pleasant than traditional classrooms.

Both students and instructors found ALCs

- To be more welcoming than traditional classrooms;
- To be more comfortable than traditional classrooms;
- To be more conducive to group work than traditional spaces; and
- To improvements in student–student interactions (Benoit, 2017, p. 22–23).

The furniture used in ALCs is essential to creating learning spaces conducive to active learning techniques. Indeed, for years students have cited the round tables and movable chairs typically found in ALCs as the most important technology in the rooms (Whiteside et al. 2010). Given the variability in budgets, desired outcomes, and spaces available in which to create ALCs, many institutions have experimented with a range of different furniture options and have shared the results with the larger learning spaces community. At the University of North Carolina, researchers evaluated the use of innovative fixed swivel desks in an experimental classroom (see Figs. 3.3 and 3.4) finding that the furniture and layout promoted student interaction, created clear pathways for instructors to move about the room and have access to students, and promoted easier transitions from one instructional modality to another (e.g., lecture to group work) (Henshaw, Edwards, & Bagley, 2011). Also, at the University of North Carolina, the combination of mobility and surface workspace led both language students and faculty to prefer an experimental tablet chair under quasi-experimental conditions (Henshaw & Reubens, 2013–14). Researchers at Buffalo State, State University of New York (USA) had students evaluate five classroom seating arrangements—modern mobile chairs, tablet armchairs, fixed tiered seating with tablet arms, rectangle tables with standard chairs, and trapezoid tables with

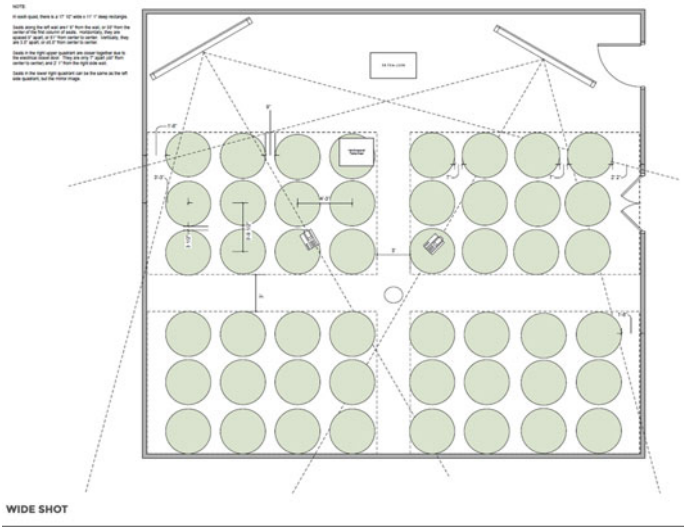

Fig. 3.3 Schemata for Peabody Hall 311, University of North Carolina Chapel Hill (*Source* www.flexspace.org)

Fig. 3.4 Peabody Hall 311, University of North Carolina Chapel Hill (*Source* www.flexspace.org)

chairs on casters—in terms of comfort and space, engagement, and interactivity. They found that students preferred the trapezoid tables and chairs on casters and modern mobile chairs to all other types of arrangements and used that data to inform furniture purchases and room designs for eight new technology-enhanced classrooms (Harvey & Kenyon, 2013).

3.4.2 Student Classroom Experiences

Student perceptions of their experiences are critical components to understanding the impact of ALCs on a host of unobservable and difficult to measure constructs. While the self-reported nature of the data may undermine its empirical reliability, we cannot and should not dismiss students' evaluation of their own experiences as end users of learning environments. Indeed, students can be far more perceptive than we might give them credit. Moreover, these experiences appear to be similar to one another despite considerable variation in geography and culture.

Students at Macquarie University (Australia) thought that courses taught by instructors who had undergone professional development opportunities to learn how to teach in ALCs were associated with higher levels of engagement, learning, and satisfaction (Robertson, 2013). At the same university, researchers found that the design and technology of active learning spaces allowed students to interact with each other and with staff more, made students more comfortable, facilitated problem-solving class styles, and made delivering student presentations considerably less awkward (Bulger, Gudlaugsdottir, Bilgin, & Robertson, 2013). Byers, Imms, and Hartnell-Young (2014) found that students taking courses in "next-generation learning spaces" at Australian schools evaluated them and their ability to engage them in the learning process significantly more positively than traditional classrooms.

Using data collected at several different institutions, researchers at the University of Tehran (Iran) found that learning spaces can and do have a positive and significant impact on students' attitudes toward engaging with one another in group work activities (Beigi & Shirmohammadi, 2012). In a semester length comparative research project, students at the Monterrey Institute of Technology and Higher Education (Mexico) experienced significant shifts in their expectations about class discussion, group work, and other active learning tasks in ALCs. In contrast to the Bethel University case cited above, researchers from Hangzhou Normal University and Southeast University (China) and National Sun Yat-sen University (Taiwan) found that elementary school students experienced greater levels of teacher support, involvement, investigation, cooperation, and task orientation in high-tech classrooms (e.g., Wi-Fi, personal iPads for each student, multiple screens, etc.) versus those with basic multimedia features (e.g., projector, teacher computer) (Yang, Yu, Gong, & Chen, 2017).

In a quasi-experimental design, students at Kennesaw State University (USA) not only perceived differences between innovative and traditional classrooms, preferring the former, but also reported significantly higher levels of learning and enjoyment. The instructors in new spaces, who were rated higher by students in terms of their organization, reported higher levels of satisfaction and received better teaching evaluations from students than did faculty teaching in traditional spaces (Hill & Epps, 2010). Researchers at Purdue University (USA) found that students evaluated the impact of ALCs on adaptability, comfort, ease of use, instructor–student interactions, variety of furniture, and ability to concentrate more favorably than traditional classrooms. Conversely, students thought ALCs had too much furniture, could become

too disorganized quickly, were too cozy (encouraging naps), and did not have enough work surface space. Most importantly, the Purdue researchers concluded explicitly what we have suggested above the student perceptions need to be included when planning learning spaces (Adedokun, Parker, Henke, & Burgess, 2017).

3.4.3 Faculty Classroom Experiences

Although most studies have focused primarily on students and their experiences, researchers are increasingly paying more attention to the faculty experience. And while faculties represent the supply-side to the students' demand-side of learning in the classroom, faculties are also end users when it comes to learning spaces. Accounting for their experiences and perceptions is also critical when evaluating innovations in formal learning environments. Indeed, Rook, Choi, and McDonald (2015) argue fiercely for the inclusion of faculty into the learning space design process given their expertise on teaching and learning, subjects about which architects may know very little.

Faculty experiences are particularly important not only because they bring an approach to teaching to learning spaces and are, in turn, shaped by those spaces, but also because they impact the students' experiences. For example, researchers compared data from courses held in Bahauddin Zakariya University Multan (Pakistan) in technology-enhanced classrooms and courses from its affiliates that were more traditional facilities. They found that instructors teaching in classrooms more conducive to active learning (with educational technology accouterments) took a more "communicative approach" to their peers (Ahmad & Rao, 2012). Oregon State University (USA) researchers found that experience matters when it comes to quality instructor–student relationships in ALCs. Specifically, more experienced teaching assistants were efficient instructors when dealing with students in ALCs (e.g., least amount of time per student; most consistent amount of time with each student) and the converse is true with less experienced instructors (DeBeck & Demaree, 2012).

Canadian researchers employed a quasi-experimental design at a 2-year public institution to test for the impact of the intersection of different pedagogies and spaces. Their efforts produced results that resemble closely the Brooks and Solheim (2014) results discussed earlier:

- Student-centered pedagogies in student-centered spaces is the most effective combination;
- Instructor-centered pedagogies in a student-centered space is not only ineffective, but may be detrimental to the teaching and learning experience;
- Learning gains are correlated positively with self-reported student-centered pedagogies; and
- Student-centered classrooms elicit more student-centered pedagogies from some instructors (Lasry, Charles, & Whittaker, 2014).

South of the Canadian border, researchers from the University of Iowa (USA) found that

- ALC environments served as catalysts to inspire instructors to redesign their courses and classroom activities to take advantage of the affordances of the technology and spaces offered;
- A flipped classroom model in which students complete didactic, lecture-based materials prior to class and engaging in active learning in class works best; and
- When faculty scaffold, rather than micromanage, learning activities, students perform well (Van Horne et al., 2014).

In a quasi-experimental study, researchers at Seattle Pacific University (USA) explored how faculty perceptions of student engagement are shaped by the intersection of pedagogical approaches and the spaces in which they are teaching. Specifically, they found that faculty found students to be more engaged in ALCs than traditional classrooms and that instructors with a stronger disposition to active learning perceive students to be more engaged in ALCs than in traditional classrooms, but the difference between less and more constructivist pedagogies persisted significantly only in ALCs (Sawers, Wicks, Mvududu, Seeley, & Copeland, 2016).

Teaching in ALCs appears to have a transformative effect on many instructors. For example, faculty who taught in ALCs at the University of Hong Kong (China) also experienced fundamental shifts in the manner in which they taught their courses and that these experiences were carried forward into subsequent courses (Salter, Thomson, Fox, & Lam, 2013). Carr and Fraser (2014) and Van Horne et al., (2014) advocate strongly for more faculty development programs centered on helping instructors learn how to teach in ALCs. Alleman, Holly, and Costello (2013) chronicle one such effort in which they discuss in detail how they designed a faculty development to overcome barriers to technology integration and provide support faculty at their American university. They found that among faculty who embraced the transition to adopting more technology, they tend to (1) use and think about it in more deliberate terms and (2) experiment with new collaborative tools more frequently. Conversely, researchers at Indiana University (USA) gathered evidence that suggest that ALCs do not exert enough power over faculty to fundamentally change their pedagogical approaches. That is, faculties who tend to lecture continue lecturing in ALCs; faculty who are more prone to constructivist pedagogies and active learning embrace the affordances of ALCs to innovate (Morrone, Ouimet, Siering, & Arthur, 2014).

In 2016, Baepler et al. published *A Guide to Teaching in the Active Learning Classroom: History, Research, and Practice* to facilitate that process. The structure of the book follows closely its subtitle, providing

- A history of the development of ALCs and a literature review of relevant research.
- Several practical chapters on
  - Common teaching challenges,
  - Assignments and activities,
  - Managing student groups,
  - Assessment and feedback,

  - Supporting all students, and
  - Supporting faculty.
- A brief how-to guide for designing learning spaces research (Baepler et al., 2016).

The authors designed the book to provide a troika of information types for the reader:

- Evidence of impact.
- Tips and suggestions grounded in research and experience.
- Help with designing research and evaluation projects.

This book is proving to be a valuable resource for those needing practical and hands-on advice for instructors and faculty developer all over the world.

3.5 Conclusion

The evidence is mounting that ALCs have an impact on student learning experiences and faculty teaching practices. Beyond engaging students more in the learning process and fomenting changes in pedagogical approaches, ALCs have been demonstrated to have a positive and significant impact on student learning outcomes as measured by grades and standardized exams. And while ALCs are being heralded as the most strategic technology in 2017 and are expected to become mainstream within the next 5 years, we still have a lot to learn about them. We would all benefit greatly from continued research and evaluation of these innovative classrooms that we have come to know as active learning classrooms or ALCs.

References

Adedokun, O. A., Parker, L. C., Henke, J. N., & Burgess, W. D. (2017). Student perceptions of a 21st century learning space. *Journal of Learning Spaces*, *6*(1), n.p.

Ahmad, S., & Rao, C. (2012). Common goals, uncommon settings: The impact of physical environment on teaching and learning English for communication. *Developing Country Studies, 2*(9), 45–56.

Alleman, N. F., Holly, L. N., & Costello, C. A. (2013). Leveraging a new building to overcome first and second-order: Barriers to faculty technology integration. *Journal of Learning Spaces*, *2*(1), n.p.

Baepler, P., Walker, J. D., Brooks, D. C., Saichaie, K., & Petersen, C. I. (2016). *A guide to teaching in the active learning classroom: History, research, and practice*. Sterling, Virginia: Stylus Publishing.

Baepler, P., Walker, J. D., & Driessen, M. (2014). It's not about seat time: Blending, flipping, and efficiency in active learning classrooms. *Computers & Education, 78,* 227–236.

Beichner, R.J. (2014) History and evolution of active learning spaces. In P. Baepler, D. C. Brooks & J. D. Walker (Eds.), *Active learning spaces: New directions for teaching and learning. J-B TL single issue teaching and learning* (Vol. 2014, no. 137, pp. 9–16).

Beichner, R., Bernold, L., Burniston, E., Dail, P., Felder, R., Gastineau, J., et al. (1999). Case study of the physics component of an integrated curriculum. *American Journal of Physics, 67*(S1), S16–S24.

Beichner, R. J., Saul, J. M., Abbott, D. S., Morse, J. J., Deardorff, D. L., Allain, R. J., et al. (2007). The student-centered activities for large enrollment undergraduate programs (SCALE-UP) project. *Research-Based Reform of University Physics, 1*(1), 2–39.

Beigi, M., & Shirmohammadi, M. (2012). Attitudes toward teamwork: Are Iranian university students ready for the workplace? *Team Performance Management: An International Journal, 18*(5/6), 295–311.

Benoit, A. (2017). Monitoring implementation of active learning classrooms at Lethbridge College, 2014–2015. *Journal of Learning Spaces*, *6*(1), n.p.

Bonwell, C. C., & Eison, J. A. (1991). *Active learning: Creating excitement in the classroom (ASHE—ERIC Higher Education Rep. No. 1)*. Washington, DC: The George Washington University, School of Education and Human Development.

Brooks, D. C. (2011). Space matters: The impact of formal learning environments on student learning. *British Journal of Educational Technology*, *42*(5), 719–726.

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

Brooks, D. C. & Solheim, C. (2014). Pedagogy matters, too: The impact of adapting teaching approaches to formal learning environments on student learning. In P. Baepler, D. C. Brooks & J. D. Walker (Eds.), *Active learning spaces: New directions for teaching and learning. J-B TL single issue teaching and learning* (Vol. 2014, no. 137, pp. 53–61).

Bulger, D., Gudlaugsdottir, S., Bilgin, A., & Robertson, G. (2013). Student engagement for a large unit in an active learning space. In S. Frielick, N. Buissink-Smith, P. Wyse, J. Billot, J. Hallas & E. Whitehead (Eds.), *Research and development in higher education: The place of learning and teaching* (Vol. 36, pp. 69–79). Auckland, New Zealand, 1–4 July 2013.

Byers, T., Imms, W., & Hartnell-Young, E. (2014). Making the case for space: The effect of Learning spaces on teaching and learning. *Curriculum and Teaching, 29*(1), 5–19.

Carr, N., & Fraser, K. (2014). Factors that shape pedagogical practices in next generation learning spaces. In K. Fraser (Ed.), *The future of learning and teaching in next generational learning spaces: International perspectives on higher education research* (Vol. 12, pp. 175–198). Bingley, UK: Emerald Group.

Choi, S. M., Guerin, D. A., Kim, H. Y., Brigham, J. K., & Bauer, T. (2013–14). Indoor environmental quality of classrooms and student outcomes: A path analysis approach. *Journal of Learning Spaces*, *2*(2), n.p.

Cotner, S., Loper, J., Walker, J. D., & Brooks, D. C. (2013). It's not you, it's the room—Are high-tech, active learning classrooms worth it? *Journal of College Science Teaching, 42*(6), 82–88.

DeBeck, G., & Demaree, D. (2012). Teaching assistant-student interactions in a modified SCALE-UP classroom. *Physics Education Research Conference, 2011,* 167–170.

Dori, Y. J., & Belcher, J. (2005). How does technology-enabled active learning affect undergraduate students' understanding of electromagnetism concepts? *The Journal of the Learning Sciences, 14*(2), 243–279.

Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okorafor, N., Jordt, H., et al. (2014). Active learning increases student performance in science, engineering, and mathematics. *Proceedings of the National Academy of Sciences (PNAS), 111*(23), 8410–8415.

Grajek, S. (2017). *Higher education's top 10 strategic technologies for 2017*. Louisville: ECAR.

Hake, R. R. (1998). Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses. *American Journal of Physics, 66*(1), 64–74.

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

Henshaw, R. G., Edwards, P. M., & Bagley, E. J. (2011). Use of swivel desks and aisle space to promote interaction in mid-sized college classrooms. *Journal of Learning Spaces*, *1*(1), n.p.

Henshaw, R., & Reubens, A. (2013–14). Evaluating design enhancements to the tablet arm chair in language instruction classes at UNC Chapel Hill. *Journal of Learning Spaces*, *2*(2), n.p.

Hill, M. C., & Epps, K. K. (2010). The impact of physical classroom environment on student satisfaction and student evaluation of teaching in the university environment. *Academy of Educational Leadership Journal*, *14*(4), 65–79.

Hoellwarth, C., & Moelter, M. J. (2011). The implications of a robust curriculum in introductory mechanics. *American Journal of Physics, 79*(5), 540–545.

Lasry, N., Charles, E., & Whittaker, C. (2014). When teacher-centered instructors are assigned to student-centered classrooms. *Physical Review Special Topics: Physics Education Research, 10*(010116), 1–9.

McArthur, J. A. (2015). Matching instructors and spaces of learning: The impact of space on behavioral, affective and cognitive learning. *Journal of Learning Spaces*, *4*(1), n.p.

Morrone, A. S., Ouimet, J. A., Siering, G., & Arthur, I. T. (2014). Coffeehouse as classroom: Examination of a new style of active learning classroom. In P. Baepler, D. C. Brooks & J. D. Walker (Eds.), *Active Learning Spaces: New Directions for Teaching and Learning. J-B TL Single Issue Teaching and Learning*, *2014*(137), 41–51.

Muthyala, R. S., & Wei, W. (2013). Does space matter? Impact of classroom space on student learning in an organic-first curriculum. *Journal of Chemical Education, 90,* 45–50.

Prince, M. (2004). Does active learning really work? A review of the research. *Journal of Engineering Education, 93*(3), 223–231.

Ridenour, J., Feldman, G., Teodorescu, R., Medsker, L., & Benmouna, N. (2013). Is conceptual understanding compromised by a problem-solving emphasis in an introductory physics course?. In *2012 Physics Education Research Conference*.

Robertson, G. (2013). Teaching to the space: Students' perceptions of learning following their teachers' participation in a programme of collaborative professional development supporting teaching in the Collaborative Learning Forum. In S. Frielick, N. Buissink-Smith, P. Wyse, J. Billot, J. Hallas & E. Whitehead (Eds.), *Research and development in higher education: The place of learning and teaching*, (Vol. 36, pp. 404–413). Auckland, New Zealand, 1–4 July 2013.

Rook, M. M., Choi, K., & McDonald, S. P. (2015). Learning theory expertise in the design of learning spaces: Who needs a seat at the table?. *Journal of Learning Spaces*, *4*(1), n.p.

Salter, D., Thomson, D. L., Fox, B., & Lam, J. (2013). Use and evaluation of a technology-rich experimental classroom. *Higher Education Research & Development, 32*(5), 805–819.

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), n.p.

Soneral, P. A. G., & Wyse, S. A. (2017). A SCALE-UP Mock-Up: Comparison of student learning gains in high-and low-tech active-learning environments. *CBE-Life Sciences Education, 16*(1), n.p.

Van Horne, S., Murniati, C. T., Saichaie, K., Jesse, M., Florman, J. C., & Ingram, B. F. (2014). Using qualitative research to assess teaching and learning in technology-infused TILE classrooms. In P. Baepler, D. C. Brooks, & J. D. Walker (Eds.), *Active Learning Spaces: New Directions for Teaching and Learning. J-B TL Single Issue Teaching and Learning, 2014*(137), 17–26.

Walczak, M. M., & Van Wylen, D. G. L. (2013–14). Tiered classrooms at St. Olaf College: Faculty and student perceptions of three different designs. *Journal of Learning Spaces, 2*(2), n.p.

Whiteside, A., Brooks, D. C., & Walker, J. D. (2010). Making the case for space: Three years of empirical research on formal and informal learning environments. *Educause Quarterly, 33*(3). Retrieved from http://www.educause.edu/ero/article/making-case-space-three-years-empirical-research-learning-environments.

Yang, J., Yu, H., Gong, C., & Chen, N. S. (2017). Students' perceptions and behaviour in technology-rich classroom and multi-media classroom. *Eurasia Journal of Mathematics Science and Technology Education, 13*(3), 621–647.

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