**The 21st Century Physics Classroom: How Research Informs Classroom Design.**

*Chris Whittaker and Liz Charles – Dawson College, Montreal, QC.*

Traditional post-secondary classroom design is largely based on facilitating the transfer of information from expert to novice: there’s a place at the front for the teacher to talk, and there are places for the students to listen – usually in front-facing rows of desks.

Modern classrooms, however, can – and should – do much more.

Instead of being passive, teacher-centred spaces, classrooms should be designed with student-centred, active-learning strategies in mind. Decades of physics education research has shown that instruction that as a rule accepts low levels of student engagement (passive learning), which is common in large classes, does not result in meaningful learning (Hake, 1998; McDermott, 1991; Redish et al, 1997). Meaningful learning goes beyond the mere memorization of facts and algorithms and requires conceptual understanding that can be transferred to new situations and problems. The gold standard for assessing the effectiveness of education. Requiring students to actively engage in their instruction (active-learning), on the other hand, can significantly improve meaningful learning in comparison to traditional lecture based instruction in college-level physics courses (Meltzer and Thornton, 2012).

So, what does a modern student-centred active-learning classroom look like? How can classroom design help maximize active-learning strategies and how can classrooms make the most of the affordances that come with modern technology?

**How Do We Learn?**

A key premise of new theories of learning is that knowledge is constructed out of one’s experiences with the world – i.e., prior knowledge (Bransford, Brown, & Cocking, 1999). Learning as such is an active process - the more you know the greater the conceptual networks available for future learning. Another facet of new theories of learning involves the argument that all higher mental functions including conceptual reasoning and formal learning develop through social interactions with others and mediated by tools (Vygotsky, 1978). Therefore learning involves the efforts to participate and use the tools and knowledge of a discipline – e.g., canonical concepts, equations, and representations. With little separation between knowing and doing (Dewey, 1915), to learn physics means to actively engage in using the conceptual tools and ways of thinking that define the field of physics.

**How Should We Teach?**

New learning theories have changed the ways we think about teaching. New models of pedagogy suggest teaching as providing opportunities and support for student participation. This is often referred to the pedagogical movement toward student-centered active learning. Examples of such pedagogies include the following: peer instruction (Mazur, cite), inquiry-based science instruction (e.g., Shore, et al., 2008) and problem-based learning (PBL; Barrows, 1985; Bransford et al, 1990; Duffy & Savery, 1994; Jonassen, 1991; CTGV, 1990, 1993), to list a few.

These new approaches owe much of their techniques to the model of instruction called *cognitive apprenticeship[[1]](#footnote-1)* (Collins et al., 1991). Cognitive apprenticeship involves making thinking visible to learners. It is a way to promote the development of domain competencies and expertise, including meaningful learning and transfer.It is made up of component processes including: *modeling* of expert performance and practices of the domain; *coaching* consisting of teachers observing students in practice; *scaffolding* of task in action; *articulation* encouraging time-on-task activities; *reflection* involving metacognitive activities at the individual, group, plenary and between novices and more experienced others; and, *exploration,* or time for inquiry. Most new pedagogical approaches can be characterized by at least one of these components. For instance, *Peer Instruction* is an example of reflection, *Just-in-Time Teaching* (JiTT), is an example of scaffolding, and Problem-Based Learning (PBL) is an example of articulation.

**From Absorbing to Constructing: A new design paradigm.**

If students construct knowledge through interactions with each other and the subject material, and if the teacher’s role in the classroom expands to include modeling, coaching, scaffolding along with managing collaborative learning strategies, self-regulation, adaptive flexibility, scripting and managing meta-cognitive processes, what elements are important in a new paradigm for classroom design?

With new ways of thinking about learning and instruction comes the time to reconceptualize how we design environments for learning. A key element is the promotion of opportunities for collaborative learning, which includes social interaction. However, creating spaces for collaborative activity alone is not enough, (Dillenbourg, 1999; O’Donnell, & O’Kelly, 1994). To take full advantage of the new learning spaces appropriate pedagogical tools and methods must be designed and implemented. Additionally, attention to time, sequencing and general management of the flow of activities becomes critical. These all fall under the heading of scripting, and orchestration.

**Some Examples.**

SCALE-UP classrooms (Student-Centered Active Learning Environment with Upside-down Pedagogies) were pioneered at North Carolina State University in the 1990’s and have steadily grown in popularity ever since – as has the evidence of their effectiveness (BEICHNER REF??, ROBIN WRIGHT REF??, Dori and Belcher 2005; Dori et al., 2007??). There are now more than 150 such classrooms across North America – including the much talked about spin-off TEAL classrooms (Technology Enabled Active Learning) at M.I.T. as well classrooms at McGill, UBC, McMaster and Simon Fraser University here in Canada.

SCALE-UP classrooms feature round tables where students work collaboratively in groups. In most cases tables seat nine, which means that it’s easy to subdivide students into three groups of three at each table. Around the walls of these classrooms are a mix of whiteboards and screens that project the contents of student computers on the tables or the teacher’s computer at the central podium. Importantly, the teacher is no longer the centre of attention – the groups are. SCALE-UP classrooms typically seat 50 to 130 students. In some cases, such as the TEAL classrooms at M.I.T., the technology also allows for a collaborative, hands-on environment where students can carry out desktop experiments and engage in interactive learning activities that use projection screens.

A newer variant of Active Learning Classrooms has recently been developed at Dawson College in Montreal. In our case, we sought to enhance collaborative group work by integrating interactive touch-screen technologies with the groups sitting at each table. Instead of using a combination of whiteboards and projectors, Dawson’s Active Learning Classrooms (DALC) features SMART Boards for each student group. SMART Boards (or Interactive White Boards - IWB - more generally) offer unique affordances when it comes to collaborative group work and in particular, they offer powerful opportunities for the creation and manipulation of shared artefacts.

In order to seamlessly integrate IWBs into the groups and in order to facilitate the exchange between all students sitting at a table, we had to re-think the table itself. Instead of a large round table with lots of space and computer screens in the middle, we decided to make the tables smaller and shaped like an oval with one end “pinched”. We also removed any obstacles on the tabletop and we placed the SMART Board at the wide end of the table. This design has many advantages:

* It brings every student within reach of any other students in the group – no one is too far away that you can’t talk with them or slide a piece of paper across to them.
* Any interaction with the SMART Board doesn’t require the students to turn away from their peers at the table – no one has their back to the board.
* The “pinched” oval shape allows for greater room between the tables – students can easily get up from any seat and access the SMART Board and it allows the teacher to freely interact with each table and their SMART Board.

**If You Build It, They Will Come – but that’s not enough**

It is important to note that classroom design is not as important as pedagogy (Charles et al. 2012). Active learning can be done in any classroom but in a classroom that is specifically designed for it, there are richer opportunities to make the most of AL strategies. The downside is that teaching in an active learning classroom effectively can be very challenging. It requires a change from the traditional teaching paradigm and it means the teacher has to do much more in the classroom. From the scripting of activities to their orchestration in class – it is not an easy thing to do well. It is therefore not enough to build new classrooms without developing the expertise to use them properly. At Dawson College, and at most of the other institutions we collaborate with, the development of expertise is done through a vibrant community of practice and/or a mentoring process coupled with professional development. Teachers who teach in the DALC meet on a weekly basis to share, learn and develop AL strategies within a technology-rich environment such as ours. We incorporate research into our community of practice in a very important way and we have a variety of disciplines using the room which brings a richness and diversity to our development.

References

Dewey, J. 1915. *The School and Society.* Chicago, IL: University of Chicago Press.

Greeno, J. G. (1998). The situativity of knowing, learning, and research. *American Psychologist, 53*(1), 5-26.

Bransford, J.D., Brown, A.L., & Cocking, R.R. (Eds.) (1999). *How People Learn: Brain, Mind, Experience, and School*. Washington, DC: National Academy Press.

Vygotsky, L.S., 1978. *Mind in Society: The Development of the Higher Psychological Processes*. Cambridge, MA: The Harvard University Press. (Originally published 1930, New York: Oxford University Press.)

Beichner, R.J., Saul, J.M., Abbott, D.S., Morse, J.J., Deardorff, D.L., Allain, R.J., Bonham, S.W., Dancy, M.H., & Risley, J.S. 2007. The Student-Centered Activities for Large Enrollment Undergraduate Programs (SCALE-UP) project. In E. Redish (Ed.) *Research-based reform of introductory physics*. Available online by searching PER Central at www.compadre.org/per

Mazur, E. (1997). *Peer instruction: a user's manual*. Upper Saddle River, N.J.: Prentice Hall.

Charles, E., Lasry, N., & Whittaker, C. (2012). *Redesigning Classroom Learning Spaces: When technology meets pedagogy and when they clash*. van Aalst, J., Thompson, K., Jacobson, M. J., & Reimann, P. (Eds.) (2012). *The Future of Learning: Proceedings of the 10th International Conference of* *the Learning Sciences (ICLS 2012) – Volume 2. pp. 207-211.* International Society of the Learning Sciences: Sydney, NSW, Australia.

Brooker, R., Matthes, D. Wright, R., Wassenburg, D., Wick, S., Couch B. (2013). SCALE-UP in a Large Introductory Biology Course. In Tricia A. Ferrett. and David R. Geelan. and Whitney M. Schlegel. and Joanne L. Stewart. and Mary Taylor Huber. and Pat Hutchings (Editors). *Connected Science: Strategies for Integrative Learning in College.* Bloomington: Indiana University Press. *Project MUSE*. Web. 15 Sep. 2013. <http://muse.jhu.edu/>.

Dori, Y. & Belcher, J. (2004). How does technology-enabled active learning affect undergraduate students understanding of electromagnetism concepts? *The Journal of the Learning Sciences*, *14*(2).

1. A sequence of methods that provide opportunities for students to observe, engage, invent and discover content and learning strategies. In doing so, students are able to see how “these strategies combine with their factual and conceptual knowledge and how they use a variety of resources in the social and physical environment” (Collins, et al., 1991). [↑](#footnote-ref-1)