STEM Education: what we know works, & why it’s not widely done

Phillip D. Long, Ph.D.
CiNO, Project 2021 & Assoc. Vice Provost for Learning Sciences
University of Texas at Austin
phil.long@austin.utexas.edu
My working life in logos

Phillip D. Long
CINO, Project 2021, Assoc. Vice Provost, Learning Sciences, ret.
Founder, Rhz Consulting, rhzconsulting.pdl@gmail.com

1971-1976

1998-2000
Nov 2014 – May 31, 2018

1984-1986

1994-1997

1990-1993

1980-1983

1978-1980

1976-1978

1974-1976

1972-1974

1970-1972

1968-1970

1971 - 1976

Passion Projects

June 2018-the future

Georgetown U
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First, a conceptual framework. 1) what do we want learners to become? 2) What kinds of experiences and activities enable that becoming? 3) What kinds of learning activities and spaces enable those experiences? and finally, 4) How do we know whether we’ve made a difference? One two big messages today is that pedagogy and learning spaces are deeply connected. 

A conceptual framework

What do we want our learners to become?

What kinds of experiences/activities enable that becoming?

What kinds of learning activities/spaces enable such experiences?

How do we know?
First, a conceptual framework. 1) what do we want learners to become? 2) What kinds of experiences and activities enable that becoming? 3) What kinds of learning activities and spaces enable those experiences? and finally, 4) How do we know whether we’ve made a difference? One two big messages today is that pedagogy and learning spaces are deeply connected.
Is there a relationship between human activity and the environment? The environment around us has profound impact on health and learning. <+> One example comes from the world of healthcare and the design of patient rooms. From 1972-1981 records from patients recovering from cholecystectomy at a suburban Pennsylvania hospital were examined to determine if patients assigned rooms with a view recovered differently from those that had not been assigned rooms with a view. 23 patients assigned to rooms overlooking a natural scene recovered more quickly (that is shorter postoperative stays), received fewer negative comments from in nurses evaluation notes, and took fewer potent analgesics relative to a matched sample of 23 control patients in rooms with views of a brick wall. This has been repeated many times since and confirmed, leading to new efforts to build hospital rooms, birthing centers and other healthcare facilities that have features intended to diminish the stress, unfamiliarity, and tension that accompany most patients in their encounters with medical and broader healthcare practices. <+>
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The hypothesis: a high versus low ceiling height prompts individuals to employ alternative types of processing (i.e., relational vs. item specific), provided that ceiling height is sufficiently salient.

A second example comes from the intersection of economic and cognitive psychology. Here researchers developed the following hypotheses: The hypothesis (read slide) With a salient, relatively high ceiling freedom-related concepts are activated, resulting in enhanced recall clustering, an established indicator of relational cognitive processing. In contrast, a lower ceiling primed confinement-related concepts, and this enhanced the average number of items recalled per cued category, a memory measure that is a known indicator of item-specific processing. The difference in appearance is really quite modest. See the High Salience/High Ceiling relative to the (high salience/low ceiling rooms. The salience or awareness of the ceiling is established by the objects hanging from it.

Effects of high or low ceilings occur because such ceiling heights increase or decrease vertical room volume, which in turn stimulates alternative concepts and types of processing. Indeed, this logic corresponds with Ed Hall’s (1966, 77) thesis that chapels versus cathedrals communicate these theorized associations (i.e., confinement vs. freedom-related) “by virtue of the space they enclose.”

You no longer need to wonder why places like the Media Lab at MIT or similar creative spaces tend to have higher ceiling heights than ‘normal’ classrooms or lab spaces. That’s good news for Markham College given the number of wonderfully high ceilings that are found in learning spaces throughout the campus!
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**TABLE 1**

<table>
<thead>
<tr>
<th>Ceiling Height</th>
<th>Associations to Activated Concept</th>
<th>Type of Processing Induced</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>Freedom-related</td>
<td>Relational</td>
<td>An emphasis on data integration and abstraction</td>
</tr>
<tr>
<td>Low</td>
<td>Confinement-related</td>
<td>Item-specific</td>
<td>An emphasis on separately analyzed and specific, relatively concrete data</td>
</tr>
</tbody>
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The kinds of spaces that are needed in higher education fall into a set of categories. Exactly what makes most sense for your institution is, however, deeply dependent on the culture of your institution. With learning space design you can begin to nudge that culture toward changes in learning and teaching practices, but only with great care. Here is a sample of some learning environments, some unusual, some common but reinvented. <+>
At Louisiana Tech University College of Engineering and Science Living with the Lab each student owns their own “lab equipment” consisting of – a laptop – tools (multimeter, dial caliper, wire strippers, …), software (Mathcad, SolidWorks, MS Office) & a robot kit (Boe-Bot) to provide a personal “lab”

• Students can conduct many lab exercises boosting hands-on learning beyond what is possible when confined to traditional fixed space laboratories.

Other schools create the equivalent of a personal lab kit for their students, though they don’t call it that or even call it out Rather, it is accomplished by leveraging a student’s personal technology, licensing software tools in community key-served fashion so students have access to it wherever they are but with custom client installers and server-based code management, give students a VPN client if it’s not built into their OS, and then their courses provide hardware kits to enrolled students for the duration of the semester. Two approaches toward the same end result.

I know that in Australia the expectation is that students don’t all have personal digital devices and that requiring them remains a hot subject of debate. That situation will resolve itself in the next few years. The vast majority of students will have such devices assuming that schools and universities make them an integrated and meaningful part of their educational experience. A small loaner pool can be provided to insure all students have the tools they need.

This is part of a larger theme - institutions should be thinking about providing what is not likely to fit into a student’s backpack, or the family’s budget. <-->
The ultimate flexible space is the black box theatre. The 'walls' may be hung as solid panels on tracks. Or they may be flexible curtain-like material. The setting is achieved by clever lighting and projection. The space becomes whatever your imagination can envision. <+>
Studio spaces provide various levels of technology affordances, but can be no more than writing surfaces, flexible mixed height seating and on your right, a projector or screen with soft seating for gatherings to leverage the “camp fire” effect, that is, conversation focused around a presenter or group of conveners. Note the <+> artifacts of prior student work hanging from the ceilings, reminders of creative solutions their peers have developed and which they too can invent. <+>

This is another version of the trend toward augmenting personal computing, and more importantly building the common software environment that a student’s machine will need to access and use.

Note the standing height tables. There is strong data to suggest that cognitive performance is enhanced by standing where the body is forced to be more active and supply oxygen to keep the body upright. And if you ask teachers here, you’ll find that many of their students prefer the standing height tables over being seated by a wide majority. But you need to have a mixed set as some may have come from work or other activities and want to sit.
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Active Learning Studio Spaces

Prototyping Space: design lab
ME310, Larry Leifer, Stanford

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Studio spaces can leverage thoughtful design elements like the one here at the University of Virginia. You see a nice seminar space with plenty of wall surface to pin drawings, images and plans on, a useful feature for design and architecture students. But the panels that appear at the left side are actually fixed to rails which not only allow them to rotate, but can be detached the base lifted out and slide down from the top to become a table.
Seminar Studio Spaces

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These active learning spaces are designed specifically for the pedagogical model based on a cycle of mini-lectures, concept questions, quizzes, hands-on experiments or project activity that repeats several times in a typical two hour class period. They usually are sized between 25 to 120 students. They are staffed by a lecturer/teacher and 2–5 assistants (advanced undergraduates, post-grand teaching assistants, etc.) They are switching from didactic content presentation to hands-on practice – that virtuous cycle I mentioned earlier.

Assessments done at UQ reveal that among other things students perceive more help and interaction among teachers and students in spaces designed like these than the same size classes taught in similar fashion in traditional flat floor classroom spaces. They take more surface area – you need to be able to circulate about, move between tables, and talk to different sized subgroups by virtue of where you stand.

A key observation found a NCSU, MIT, and other institutions is that not only does it require a redesign of the curriculum to leverage these spaces, but where a course has been designed and developed by someone else, a new teacher needs to have both an orientation to the space but also some time as an apprentice to a master teacher who knows how to use the space so they can become familiar with how this learning environment works. The key attributes are the writing surfaces, and the table screens, including the ability to send from the teacher’s workstation content to the table screens as well as allow any table screen to be displayed across the room.
Where you need to teach with larger numbers of students, or you want to bring larger numbers together and still have interaction, having the floors rise with every other row of desks allows students to simply turn around and have eye-level conversations with their classmates.
At times you only have raked lecture theatre spaces – but they can be redesigned with active learning in mind, leveraging the vertical spacing in a positive way. Here you have a space from the University of Birmingham followed by a chemistry learning lab at the University of Melbourne. This is not quite Scale-Up or TEAL in that the students can do some, but not all the hands-on experiments at their tables – these do not entirely replace the discipline labs as Scale-Up does in Physics. But they provide dry table top work space and demonstration wet labs, on a small scale.
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Another emerging trend is to leverage new table designs - like the so-called pac-man table shown here. Round tables are great for collaboration. Having the slice in them with the two parts rotating around the center post lets a students orient themselves to face a give direction when desired, but also lets the teacher choose to walk up and talk to half of the students at a table, set back and talk to the entire table or step back further and talk to students at a subset of the rooms tables.
Another trend is shown here at the LINC Center at Oregon State University. It is a large auditorium that seats 588 students in circular setting. It is notable that despite its size the distance from the edge of the furthest student is only 8 rows. A traditional large lecture space surprisingly uses much more area. Then one shown here looks bigger than the round space we just saw, but seats only 400 [The link at the bottom is to a video from Bora Architects]
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And don’t forget what has become a pressing need at many colleges is informal spaces for study. While in the k12 environment the students are in effect captives on the campus for the duration of the day, it is significantly better for learning if they desire to stay and have places they are attracted to to do academic work. Creating attractive spaces is one effective way to accomplish this.
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Nonformal spaces can mimic cafes with booths that have large screens for sharing work. Or where you have hallways or other corridors, you may be able to redesign them to create spaces for students to step out of the traffic path and work together.
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LEARNING SPACES NEED TO BE RE-THOUGHT IN TERMS OF THEIR USE ACROSS A 24 HOUR DAY

And increasingly common is recognition that university infrastructure needs to be leveraged to provide value across the 24 hour diurnal cycle. Daytime and early evening use supports the primary goal of learning. But those same spaces can be used after the primary teaching hours for recreational or co-curricular activities. This is Wallenberg Hall at Stanford where students are working on class projects in this image, but the same space is available after class hours for to offer computer games for recreation and relaxation.
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Learning space designs pre-dispose types of interactions, making some easier to do and some harder to do. In STEM the trend is toward active learning spaces.

But spaces predispose they do not force. A good teacher can make a poorly designed room a great learning environment, but she'll have to really work to do that. And a good learning environment that has not been developed with pedagogy to leverage it will never be offer a great learning experience for students. Teaching and learning space design are an ensemble.
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So now the question is, does active learning really work? Many different measures have been explored. Physical activities, if well designed, can significantly augment learning. That’s the ‘embodied cognition’ measure.

Active learning has been studied with failure rates as the dependent variable.

And improved learning outcomes, the primary goal of any designed learning activity have been studied in various experimental paradigms through A/B testing and using the instructor as their own control to minimize variance in teaching ability.
Activity reinforces learning—Embodied Cognition

- Context: Physical experience of angular momentum vs. observation
- Mechanism of action: dPMc, M1/S1, SPL activation

Research by Carly Kontra and colleagues at the University of Chicago and DePaul University demonstrated in 2015 that experience with concepts that have a physical component to them, like angular momentum, increased involvement of sensorimotor brain systems during students’ subsequent reasoning and aided their understanding. Even brief exposure to forces associated with angular momentum, significantly improved quiz scores. These physical experiences activate sensorimotor brain regions when students later reasoned about angular momentum. Hence, there is a clear neurophysiological mechanism underlying the value of physical experience in science education.

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Among the STEM community physics has often taken a more active role looking at teaching and learning practices. This study by a couple of Carl Wieman’s students along with Carl looked at the pedagogical approach of deliberate practice to develop expertise. Here deliberate practice took the form of a series of challenging questions and tasks that required the students to practice physicist-like reasoning and problem solving during class time while provided with frequent feedback.

The comparison was made between two large sections (N = 267 and N = 271) of an introductory undergraduate physics course. They found increased student attendance, higher engagement, and more than twice the learning in the section taught using research-based instruction. Effect size was 2.5 std. deviations, obtained with trained personal tutors, and the largest ever measured in an educational study to date.
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The message I want to emphasize is that there have been hundreds and hundreds of studies on active learning over the past more than 3 decades that have consistently produced similar results. This is significant because lecturing has been the predominant mode of instruction since universities were founded in Western Europe over 900 years ago. This study by Freeman and colleagues in 2014 is currently the largest meta-analysis to date of STEM learning, fully 225 studies studying lecture vs. active learning in STEM classes. He looked at failure rates and performance on concept tests as two dependent variables that tended to be included in the majority of studies on the impact of teaching method across hundreds of published reports.

Take failure rates - The average failure rate decreased from 34% with traditional lecturing to 22% with active learning. This odds ratio is equivalent to a risk ratio of 1.5, meaning that on average, students in traditional lecture courses are 1.5 times more likely to fail than students in courses with active learning. There is no significant difference attributable to the STEM discipline.

The second graphic is another view of this failure rate data showing kernel density plots of failure rates under active learning and under lecturing. The mean failure rates under each classroom type (21.8% and 33.8%) are shown by dashed vertical lines. The second variable focused on concept learning, and concept inventories are typically done in pre and post test formats. Active learning methods are designed to have the student working on tasks that simulate an aspect of expert reasoning and/or problem-solving while receiving timely and specific feedback from fellow students and the instructor that guides them on how to improve. These elements of authentic practice and feedback are general requirements for developing expertise at all levels and disciplines. The differences are larger for concept inventories relative to instructor created exams, which is consistent with other findings that concept inventories tend to address higher order cognitive constructs, e.g., misconceptions rather than mastery of quantitative problem solving. Further, the effect is stronger on smaller class sizes than larger ones, thought the effect is significant on all class sizes. The effects were just a pronounced whether the course was major’s course or not, and whether the course was upper or lower division.

Finally, many criticisms often emerge based on concerns that study publication bias – that is, you don’t see published the studies that were made and didn’t achieve 0.5 p-values. The authors then broke the studies up into four groups based on how well the studies met the criteria for inclusion in the analysis. An extensive Supplemental Information addendum to this publication in PNAS gives details about the inclusion criteria that is accessible from a link with in the paper. I won’t go into this in detail here but I do want to say that the four groups created based on how closely they adhered to the the inclusion criteria were analyzed for heterogeneity based on methodological quality.
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Freeman et al. did look at recent analyses of 143 randomized controlled medical trials that were stopped for benefit and found that they had a median relative risk of 0.52, with a range of 0.22 to 0.66 (15).

In addition, best-practice directives suggest that data management committees may allow such studies to stop for benefit if interim analyses have large sample sizes and P values under 0.001 (16). Both criteria were met for failure rates in the education studies we analyzed. The average relative risk was 0.64 and the P value on the overall odds ratio was < 0.001.
If medical interventions had treatment effects equal to these student failure rates what would happen?

• They would be stopped for benefits!

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Brain EEG during different activities

ERIC MAZUR at Harvard is fond of showing images of EEGs, that reflect brain activity in different contexts. Here you see a sample of several days (the rows) with different activities labeled within the rows for their types. And on the far right <+> of each the brain activity in typical <+> lecture oriented classes. But note the lab class <+> where there is active learning.
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There are better instruments emerging to get a sense of the kind of learning and pedagogy that faculty are using in STEM teaching. Carl Weiman and his wife Sarah Gilbert have devised the Classroom Observation Protocol for Undergraduate STEM (COPUS)
Here are abbreviated descriptions of the list of inventory items that receive points on the rubric sorted according to general factors that support learning and teacher effectiveness, along with references on their impact.

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A fundamental truth of learning

Why is self-report so notoriously unreliable? There is a fundamental truth about human learning. A well known student of the complexity of human behavior, John Cleese points out one of the major challenges in self-reported data. <++>
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People are poor at evaluating their own learning, because it is difficult to know what you do not know.
In social psychology this is often referred to as the Dunning-Kruger Effect. And this has been humorously described by none other than John Cleese of Monty Python fame. He uses a fair bit of hyperbole to emphasize the explanation to humorous effect. This is part of a longer monologue respond to Python fans questions which you can find on YouTube. I came across this quite accidentally as he described what he felt the problem with why some people have such difficulty learning from clear feedback.
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What is the current state of the 25-30 year push toward active learning in the STEM classroom?
Criticism of research on the effectiveness and use of active learning practices in STEM subjects has largely been leveled at those publications using self-reported scales as the primary form of data collection. Actual observations of classrooms were needed. Marilyn Stains and her merry band set out to observe the behaviors of faculty and students in 25 universities in the US and Canada. She used the Classroom Observation Protocol for Undergraduate STEM (COPUS) instrument which has the observer record everything that happens during the observation period and codes the behaviors occurring in successive 2 min. intervals - aka Interval Behaviour Sampling. It asks observers to record the co-occurrence of 13 student behaviors (e.g., listening, answering questions) and 12 instructor behaviors (e.g., lecturing, posing questions).
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I want to walk you through their findings. First, the raw behaviours observed were grouped using Latent Profile Analysis creating clusters based on four instructor behaviors (lecture, posing questions directly to the audience, clicker questions, and one-on-one work with students) and four student behaviors (group work on clicker questions, group work on worksheets, other group work, and individually asking questions). These were selected because they were observed showing good variance, weren’t highly correlated with one another and likely to differentiate between active and non-active learning environments. Cluster 1 had no observed student involvement except sporadic questions. Cluster 2 had clicker questions sometimes associated with group work. Together the first two clusters were labelled “Didactic” which constituted a wider swath of lecture-based teaching methods, accounting for 54% classroom activities (the paper has an addition typographical error).
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Observations in large courses were classified in the didactic instructional style more than expected by random chance and in the student-centered instructional style less than expected by chance, whereas the opposite occurred for small courses. This follows a general perception that large courses are often taught in lecture format. But remember there has been more than a decade of work to introduce both interactive and student centered teaching approaches into teaching of large lectures.

Classrooms with flexible seating were more likely to be classified in the student-centered instructional style. But about still a little less than half of the classes with flexible seating were classified as didactic. This reinforces the notion that classroom design predisposes but is insufficient to directionally change teaching practices. They must be coupled with other faculty development interventions.

No significant relationships between instructional style and course level, suggesting that instructional style is similar throughout the curriculum.
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Relative to chance, mathematics and geology have more student-centered styles than expected, biology has more interactive styles than expected, and chemistry has more didactic styles than expected.

That leaves engineering and physics, which in this analysis were not statistically differentiable in terms of any preponderance of teaching methods, this despite decades of research and interventions that have attempted to shift the mode toward interactive and student centered teaching practices. The charitable view is it may have separated them from the chemists. The more critical view is how have these efforts failed to statistically move the needle?
Looking across STEM disciplines

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What's going on??

Despite years of observation, data collection and analysis, showing active learning in one form or another seems to have measurably better student learning outcomes than more passive didactic teaching practices, Stains et al., conclude that more than 70% of the observations they made reflected didactic modes of teaching.
Recently Carnegie Mellon University confronted this question head on. They are an institution who arguably epitomizes a deep commitment to evidence-based research to guide the improvement of learning outcomes. They do this not only for their own students but as a major research focus of the institution, exemplified by the Simon Initiative. Herb Simon is the person who coined the phrase learning engineering and recognized early on that teaching is a team sport not a lone faculty enterprise.

And yet at their own institution the realized that several large scale and long duration research efforts like the Open Learning Initiative which has spent more that decade investigating the details of how learners approach, overcome and master learning with an intensive focus on just a few courses and disciplines, most well known being introductory statistics. And yet, in spite of their work, their own faculty have been no more willing to redesign their courses nor leverage technologies shown to measurably improve learning outcomes. Why is that? Especially here of all places?
The focus of research on the adoption of new pedagogical practices and supporting technologies is complicated by our limited understanding of the institutional and cultural factors embedded in implementation strategies and processes that hinder or promote the adoption of new instructional tools and practices. They are often guided by the uncoordinated and poorly or unreported efforts of researchers, universities, and commercial enterprises, leaving each new effort to reinvent the wheel. Organizational factors influence the acceptance of—or resistance to—innovative practices, as well as the development of the new practices required to effectively and consistently maintain them.
These efforts are often described as course transformation, innovation, design, and development projects. This was designed in two phases:

1) ethnographic observation, interviews, case studies, digital ethnography, document analysis, and textual analysis of the four projects. During this first phase, a survey instrument was also developed and deployed to a larger population of faculty on campus.

2) Results from the survey were used to inform the direction and focus of components of the remaining months of ethnographic observation.

The researcher presented to respondents vignettes that described hypothetical social situations and asked for their judgment about those situations. Each situation had a number of variables with many possible combinations. This is a factorial survey design.
Misalignment frequently derailed projects while often remaining unidentified by project members. In cases where misalignment exists but is not noted, people believe that they understand shared goals but in fact have different understandings of their roles or of the — shared goals.

But the most destructive miscommunications are in fact experienced by all participants as successful, comfortable communication: miscommunication is unnoticed and has persistent effects on the collaborative efforts. The project is either succeeds or fails as it passes through these interstitial, high-stakes transitions from one stage of an effort to another.
Complex projects bring a myriad set of possibilities for misunderstandings, assumptions and interpretations that may not be shared or in which there is a strong belief they are but that is mistaken. There may be different individuals who bring their own views about why the project has been conceived; differing perceptions of its originality, the pedagogical roles involved or disciplinary context into which it is set; measurability of both intended as well as secondary effects may differ, be hard to capture or simply not perceived; commercial interests among the participants may vary or styles of interaction with commercial vendors may be at odds among team members;

There are equally rich characterizations of types of collaborative efforts themselves, of the personnel and their characteristics, and the phenomenon of constant re-evaluation of a project that each project member engages in assessing their levels of commitment, autonomy and ownership. This led to Herckis & Smith's descriptions of "soft membership" versus "hard membership" in projects. <<>

Note these project all involved at least 15 people.
Characteristics of complex adoption projects

- different originators of each concept
- target pedagogical role and disciplinary context
- mutability, reliability, and complexity of the product
- measurability of product intended effect(s)
- presence, measurability, and relevance of secondary and unintended effects
- incorporation of commercial elements
- perceived quality and value by faculty, administration, end user(s), and colleagues

Soft membership confers flexibility which allows motivated individuals to make significant progress independently and promotes creativity and innovation. This flexibility also, however, leaves space for hesitance and exclusion.

Hard membership roles and responsibilities are explicit, but are often perceived as rooted in mistrust of collaborators, a desire for power, or a lack of respect for collaborator skills and autonomy.

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Innate Dimensions of “Good” Teaching

The importance of being a “good professor” contributes to risk-averse teaching strategies

At the two ends of this axis there are those for whom teaching is something that must come from a private wellspring, —from the heart and learned —by intuition. These innate mindset individuals may believe that teaching skills can be honed, but do not believe that they can be taught.

A second group of faculty believe that instructional skills can be learned and taught. These learned mindset faculty often seek out new methods and approaches, advice, research, and mentorship.

A second dimension is Experiential. This has four categories: relational, content-focused, measurable & practical

Relational models are built on inter-personal experiences with emotional valence. An academic staff with such a model will say good teaching is about personal relationships in which they grew, with parents, mentors and beloved professors. The key here is good teaching establishes an emotional connection.

Content-focused models of good teaching are focused on organization and delivery of disciplinary content. Faculty with a content-focused model will describe well organized presentation of problems, clear language choices and passionate lecturers who put content first. Learners receive this wisdom. There is a tendency to describe “ah-hah” moments in their teaching when students suddenly get what she’s talking about.

Measurable models of good teaching emphasize quantitative data, especially student test performance, faculty ratings from student evaluations, & assessments related to mastery learning outcomes. Many of you have heard or read work by Eric Mazur who describes how well he thought his students were learning until he finally administered the Force Concept Inventory and after a masterful term of teaching, so he thought, the FCI revealed his students had learned precious little about the core concepts in Newtonian physics. This hit him especially hard and led to the his development of peer instruction. External measures are profoundly important and revealing to them.

Practical models of good teaching place a heavy emphasis on student experiences through active engagement. Faculty with this model relate to their formative learning experiences in which they engaged in unfamiliar tasks guided by those with more experience. The struggled with their own lack of mastery and ultimately improved accompanied by a deep sense of accomplishment.

These are not, of course, mutually exclusive. We’re talking about messy human cognition here. A faculty member might have an innate & practical mindset. She challenges her students forcing them to struggle through a problem set. She prides herself in developing appropriate challenges. Suggesting she work with someone who not similarly equipped with this expertise be it a lack of disciplinary expertise, theoretical orientation or teaching experience would be reject out of hand as a waste of time. Some with a learned mindset focused on measurable outcomes might seek new teaching or technology supported learning models, but only if there were measurable outcomes. Indeed, he might try introducing a new method in a module of his course, but be unwilling to consider revising his entire course so he could fall back to the traditional methods if the week’s module test results didn’t show a better result than his previous methods. An extended commitment would be too risky and difficult to accept if it returned disappointing results.
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We faculty are human. We interpret the world through our models of it. We must uncover those models of good teaching.
A Common Problem

We have data
We have knowledge

Is our problem simply updating our knowledge?

The knowledge that particular pedagogical practices lead to better learning outcomes, yet remain far from widely adopted in STEM is not unique to STEM.

How many of you know this person? Unfortunately, Hans Rosling passed away last year, a tremendous loss to epidemiology, public health, and teaching. I, like many of you, was introduced to Prof. Rosling, in 2006 at the first TED Talk in Monterey, California, where he gave a mesmerizing presentation on the misunderstood realities of the successes and progress in public health around the world. He had been testing audiences, from his students at the Karolinska Institute to his professional colleagues when he gave talks around the world, asking them about infant mortality rates in different countries, immunization rates and life expectancies.
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Let’s watch this short introduction from this first TED Talk. Notice Prof. Rosling said the problem wasn’t their lack of intelligence, it was their “preconceived ideas” - that is, he thought, their level of contemporary knowledge when it came to population health. And he sought out to eradicate that ignorance spending the next 10 years traveling the world over giving talks, meeting with politicians, attending and talking at the World Economic Forum and so on. He developed GapMinder animation software for data. If you watched the rest of this lecture you’d see one of the most animated, and I have to say for a scientist, thrilling presentations of longitudinal data, including an instant replay of the changing data to audience applause.

But after doggedly pursuing this goal of improving the general understanding of population health data he came to realize that something else was going on. The ignorance couldn’t be fixed by providing clearer data animations or better teaching tools. People loved his lectures, but they were not HEARING them. Then, a decade later, he gave a talk at Davos to the most well educated world leaders, economists and population health professionals in the world. He gave his pre test asking about poverty, population growth and vaccination rates. He was sharing the stage with Bill and Melinda Gates. His audience got the poverty question right at a ‘stunning’ 61%. The other two questions they did worse than the chimps. We have to see the world differently - recognize our world models and understand our cognitive predispositions.
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Teaching STEM better demands humility, work, & culture change

• faculty identify as professors
• faculty identities feature teaching as a strong and sometimes primary component.
• But P&T + institutional priorities are often contradictory

This wasn’t about ignorance. It was about their model of the world. Rosling concluded that the problem is about is a result of how are brains work, how we have evolved over millennia, discovering what Daniel Kahneman and Amos Tversky called the theory of heuristics in their classic paper in 1974, “Judgment under Uncertainty: Heuristics and Biases” [Science, New Series, Vol. 185, No. 4157. (Sep. 27, 1974), pp. 1124-1131]

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This was later popularized in Kahneman’s book “Thinking Fast and Slow” But to teach better in STEM or any discipline where knowing how the world really works is critical requires we take a step back and rethink our models of learning and of the world itself. Rosling calls it Factfulness - replacing overdrastic interpretations of the world, or your models of it, with data from the world itself. He offers ten dimensions to help you build your capability at doing this. Others have different approaches but as the work of Lauren & Joel are helping us see, these same issues pertain to adopting new pedagogical practices.
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The vast majority of faculty coming out of Ph.D. programs around the world reflect a lack of training and preparedness for their teaching responsibilities. When one's model of teaching is more toward the innate end of the spectrum the abundance of opportunities for profession development and training in instruction are interpreted as useful for “them” - and availing oneself of these resources reflects personal or professional inadequacy.

We expect faculty who are hired and have little training in instruction to launch into their teaching while building their research programs. This reinforces the notion that teaching is not something which one can learn about. No time is allocated for it - it must not be necessary. The
The Bottom Line

We need a model of implementation science for post-secondary education

An implementation science for postsecondary education represents an evidence-based approach to understanding and refining the implementation of science-based, technology-enhanced instruction in higher education. We can turn to biomedicine for help as they have been working for decades to transition from a purely clinical model of teaching to an evidence-based practice model of medical care. Implementation science comprises a diverse suite of research protocols and theoretical frameworks which take an empirical approach to evaluating effective interventions, designing research protocols, identifying strategies which can produce the greatest impact, tracking outcomes, and defining barriers to uptake of evidence-based interventions across diverse real world contexts. It is being used in community health, early childhood education, organizational behavior, epidemiology, social work, and a rapidly growing number of other disciplines. We do parallel things in the emergence of Centers for Translational Research. We need to do similar things for higher and tertiary education.
I've never quite understood why prototyping learning spaces has been a relatively obscure activity rather than a featured practice of higher/tertiary education. The opportunity for community building, the ability to bring one's research mentality to the classroom, and most significantly from a senior administrator's perspective, the chance to avoid mistakes & save money, or bring the data to light that supports costly infrastructure decisions seems hard to pass up. But in most universities, it's probably there isn't a conscious decision to do any of this because the value of the practice has been largely invisible.
PROTOTYPE WHAT?

Activities
PROTOTYPE WHAT?

As
Prototyping can be done in any space, but it’s helpful to have some place that can support prototyping of services, pedagogical practices and physical design options. At the University of Queensland I was fortunate enough to have the privilege to design such a space for the Centre for Educational Innovation & Technology, essentially my lab space, which occupied the top two floor of the Learning Innovation Building, which I also helped design. Note the double height space based on my earlier comments about creativity and ceiling heights.
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PANORAMA OF PROTOTYPING LAB
CEIT UQ

Video Capture Studio
Scaffolding Folded Tables Huddle Boards

Sensor Corner Main Prototype Space Sliding Doors
Whiteboard on Lab side, multi-surface on planning side

Project Planning
Complex Systems

Lexus

Cardboard functional model
Complex Systems

Lexus

Cardboard functional model
Lexus Cardboard functional model

Between laser cutters & 3D printers you can fabricate nearly anything quickly with inexpensive materials at relatively overall low costs.

Especially if you have students doing the bulk of the 'play'.
Measure:

• Prototyping extends not just to things, but to behavior – *prototype learning activities*.

• Document examples of your teaching practices you seek to explore.
Prototyping Pedagogical Practice

Prototyping Pedagogical Practice

Prototyping Pedagogical Practice

What do we want our learners to become?

What kinds of experiences/activities enable that becoming?

What kinds of learning activities/spaces enable such experiences?

How do YOU know?

A conceptual framework

Learning Spaces Collaboratory, 2013
What do we want our learners to become?
What kinds of experiences/activities enable that becoming?
What kinds of learning activities/spaces enable such experiences?

A conceptual framework
Pedagogy & Space are deeply interconnected

How do YOU know?

Learning Spaces Collaboratory, 2013
Thank You

Phillip Long, Ph.D. Assoc. Vice Provost
Learning Sciences, University of Texas at Austin
Thank You

Phillip Long, Ph.D. Assoc. Vice Provost
Learning Sciences, University of Texas at Austin Ret.
RHz Consulting, LLC, rhzconsulting.pdl@gmail.com
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References: Team-based Learning


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⁠¹Sacha Zyto, David R. Karger, MIT CSAIL, Cambridge, MA 02139, USA, sacha@mit.edu, karger@mit.edu

⁠²Mark S. Ackerman, Univ of Michigan, Ann Arbor, Ann Arbor, MI 48109, USA, ackerm@umich.edu

⁠³Sanjoy Mahajan, Olin College of Engineering, Needham, MA 02492, USA, sanjoy@olin.edu

References