127th ASEE Annual Conference
June 21-24, 2020 | Palais des congrés de Montréal | Montréal, Canada

Paper ID #28889

WIP: An Ecosystems Metaphor for Propagation

Dr. Susan Bobbitt Nolen, University of Washington

Professor Emerita of Learning Sciences & Human Development

Dr. Milo Koretsky, Oregon State University

Milo Koretsky is a Professor of Chemical Engineering at Oregon State University. He received his B.S. and M.S. degrees from UC San Diego and his Ph.D. from UC Berkeley, all in Chemical Engineering. He currently has research activity in areas related engineering education and is interested in integrating technology into effective educational practices and in promoting the use of higher-level cognitive and social skills in engineering problem solving. His research interests particularly focus on what prevents students from being able to integrate and extend the knowledge developed in specific courses in the core curriculum to the more complex, authentic problems and projects they face as professionals. Dr. Koretsky is one of the founding members of the Center for Lifelong STEM Education Research at OSU.

WIP: An Ecosystems Metaphor for Propagation and Student Learning

Introduction

In the context of broadening participation in engineering, the engineering education community has recently been discussing the merits of shifting from a pipeline or pathways metaphor to an ecosystems metaphor (Cheville, 2019; Lee, 2019; Lord et al., 2019). In short, the ecosystem metaphor takes a socio-cultural perspective that is local, idiosyncratic, historic, and context- and climate-centered (Engeström, 2001). It sees students as active agents in their learning and foregrounds connections and community that students' experience (Cheville, 2019; Lee, 2019). Ecosystems are complex, and intentional changes in any aspect of the system lead to other aspects responding, often in unanticipated ways (Cheville, 2019; Lord et al., 2019).

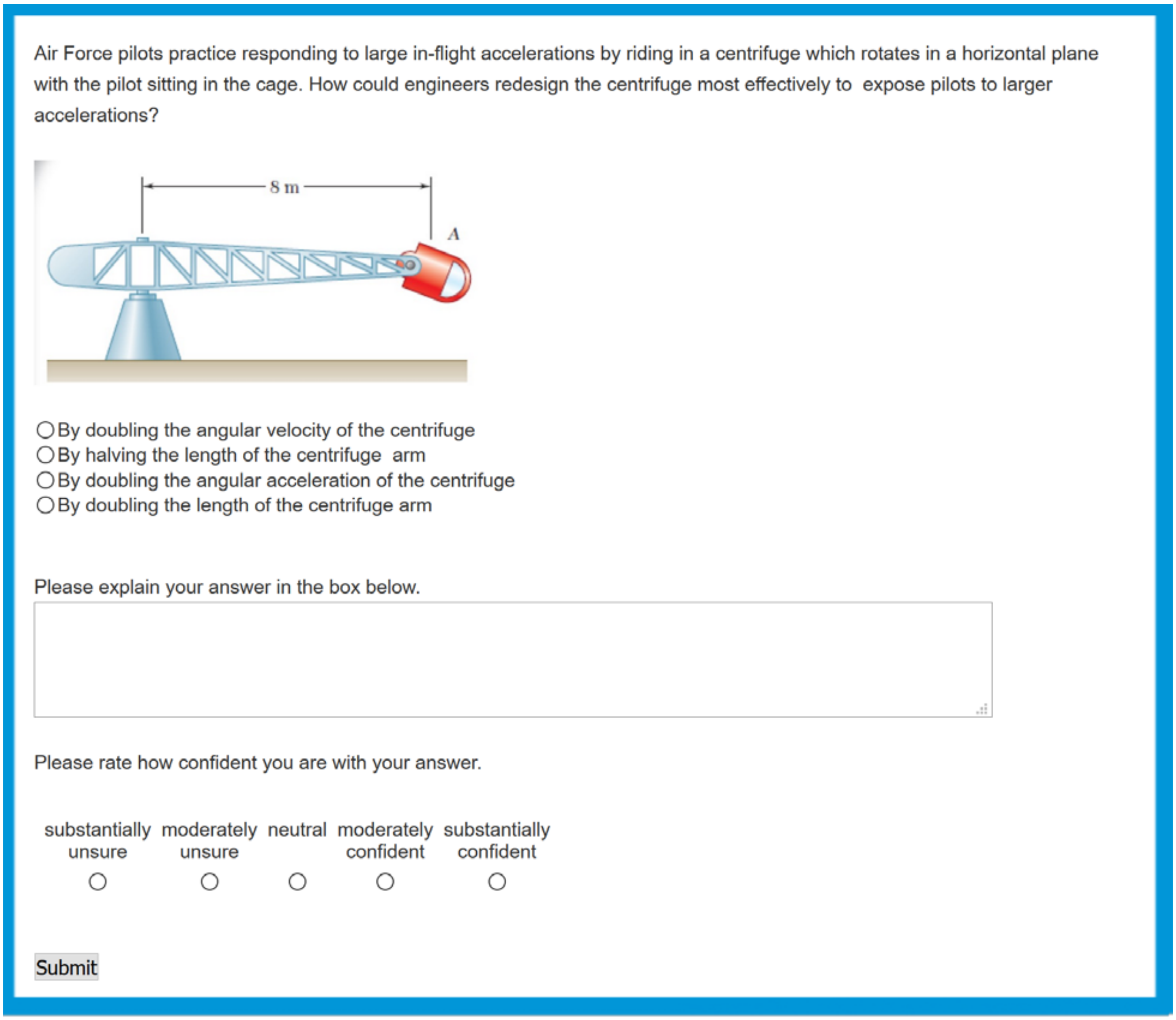
In this work-in-progress paper, we apply the ecosystems metaphor to develop a model to address the ways a technology-based tool, the Concept Warehouse (Koretsky et al., 2014), propagates in diverse settings and to how students use the tool in their learning. The ecosystem model goes beyond previous research using the Diffusion of Innovations framework (Rogers, 2005). While Diffusion of Innovations has been applied to educational innovations in engineering education (Borrego et al., 2010), physics education (Henderson and Dancy, 2008), and medical education (Rogers, 2002), it does not adequately account for the ways in which instructional and learning practices are socially situated within specific educational ecosystems, nor how those systems influence the ways in which practices are taken up by individuals and groups.

This WIP serves as the theoretical basis for a larger project in which we seek to propagate the Concept Warehouse, a technological innovation designed to foster concept-based active learning, into Mechanical Engineering. We seek to characterize the ecosystems across five diverse institutions with different resources and serving different populations of students in order to illuminate the reasons for variations in propagation, use, and impact of the Concept Warehouse. What we learn will inform future efforts to spread evidence-based practices to a greater range of contexts, instructors, and students. It will also inform further development of those practices and their evidentiary base through the documentation of instructor modification and implementation of the Concept Warehouse. The intent for this paper is to provide an opportunity for community discussion so we have opportunity to revise the model before intensive analysis is conducted.

The Technology Tool

The Concept Warehouse is a web-based instructional tool that was originally developed for Chemical Engineering faculty (Koretsky et al. 2014). It is designed to provide instructors and their students with a cyber-enabled infrastructure to deliver concept-based active learning. C*oncept-based active learning* is the use of activity-based pedagogies whose primary objectives are to make students value deep conceptual understanding (instead of only factual knowledge) and then to facilitate their development of that understanding. Concept-based active learning has been shown to increase academic engagement and student achievement (Deslauriers et. at, 2011; Freeman et al., 2014; Hake, 1998), to significantly improve student retention in academic programs (Freeman et al., 2014; Prince, 2004), and to reduce the performance gap of underrepresented students (National Research Council, 2011, 2012; Haak et al., 2011; Theobald et al., 2020)

The Concept Warehouse provides three distinct but complementary functions: (a) a content repository, (b) an audience response system to deliver content, and (c) learning analytics that provide data to instructors and researchers. It houses over 3,000 *ConcepTests*, which are short questions that can rapidly be deployed to engage students in concept-oriented thinking and/or to assess students' conceptual knowledge, along with more extensive concept-based active learning tools and concept inventories. Screenshots of students' views of a ConcepTest and an instructional tool developed during this project are shown in Figures 1 and 2, respectively. The Concept Warehouse has grown rapidly over the last five years with over 1,200 faculty accounts and 28,000 student users (Friedrichsen, Smith, and Koretsky, 2017).



Air Force pilots practice responding to large in-flight accelerations by riding in a centrifuge which rotates in a horizontal plane with the pilot sitting in the cage. How could engineers redesign the centrifuge most effectively to expose pilots to larger accelerations?

○ By doubling the angular velocity of the centrifuge
○ By halving the length of the centrifuge arm
○ By doubling the angular acceleration of the centrifuge
○ By doubling the length of the centrifuge arm

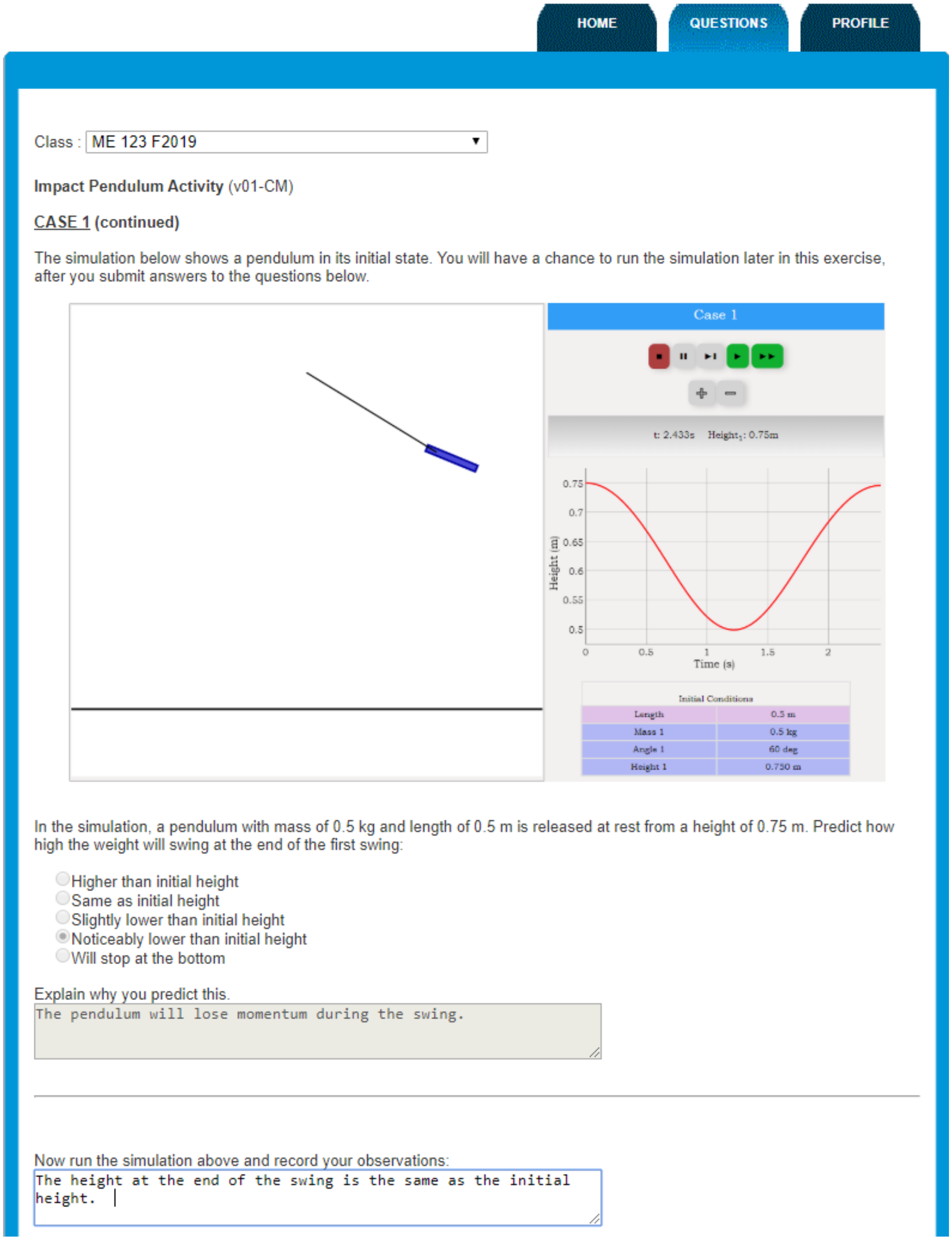
Please explain your answer in the box below.

Please rate how confident you are with your answer.

substantially unsure	moderately unsure	neutral	moderately confident	substantially confident
○	○	○	○	○

Figure 1. Screenshot of the Student Interface of a ConcepTest for Engineering Dynamics. The instructor has the option to request written explanations and confidence when assigning the question.

While the Concept Warehouse has demonstrably propagated in Chemical Engineering, the mechanisms for successful spread to diverse settings have not been studied. We start from the assumption that faculty choose instructional practices not in isolation, but in relation to the specific *educational ecosystems* in which they teach. Given the diversity of post-secondary institutions, it is likely that innovations like the Concept Warehouse are more readily taken up in some than in others. For example, in institutions that provide professional development opportunities for faculty, new users of Concept Warehouse may receive formal or informal support. Other institutions may emphasize other activities (i.e., research) and provide little support or encouragement for faculty to adopt new techniques.



Class : ME 123 F2019

Impact Pendulum Activity (v01-CM)

CASE 1 (continued)

The simulation below shows a pendulum in its initial state. You will have a chance to run the simulation later in this exercise, after you submit answers to the questions below.

Initial Conditions	
Length	0.5 m
Mass 1	0.5 kg
Angle 1	60 deg
Height 1	0.750 m

In the simulation, a pendulum with mass of 0.5 kg and length of 0.5 m is released at rest from a height of 0.75 m. Predict how high the weight will swing at the end of the first swing:

○ Higher than initial height
○ Same as initial height
○ Slightly lower than initial height
● Noticeably lower than initial height
○ Will stop at the bottom

Explain why you predict this.

The pendulum will lose momentum during the swing.

Now run the simulation above and record your observations:

The height at the end of the swing is the same as the initial height.

Figure 2. Screenshot of the Student Interface of an Inquiry Based Activity for Engineering Dynamics.

The Ecosystem Model

Features of an innovation, along with is basis in research, contribute both directly to instructional practice and to instructor beliefs. To more fully understand propagation and impact, however, we take an ecosystems approach as illustrated in Figure 3. Instructional decisions are made in relation to the perceived value and feasibility of a practice within particular institutional contexts (Nolen et al., 2009, 2011). Value of an innovation may depend in part on whether its features meet a current need (e.g., to support active learning in a large lecture), but also depend on broader contexts (e.g., departmental valuing of teaching vs. research, instructor's job security, importance of the need). Feasibility may depend on time needed to learn to use the innovation effectively, availability of institutional or peer support, or magnitude of the instructional change. While instructors' use of the Concept Warehouse (hexagon in Figure3) is influenced by their beliefs regarding the features of the innovation (diamond), these beliefs are socially constructed across time within institutional and community contexts (ovals in Figure 3). In addition to current contexts, decisions may be informed by instructors' diverse histories, by observations of student practices, student histories, and student learning outcomes (feedback loops). Student outcomes result from student practices and histories (e.g., familiarity and valuing of conceptual vs. procedural problems) within the learning context (class size, instructional practices including Concept Warehouse, availability of support). We argue that our findings will inform attempts to effectively transfer educational research into educational practice and expand participation of groups, institutions, and geographic regions that are underrepresented in STEM disciplines.

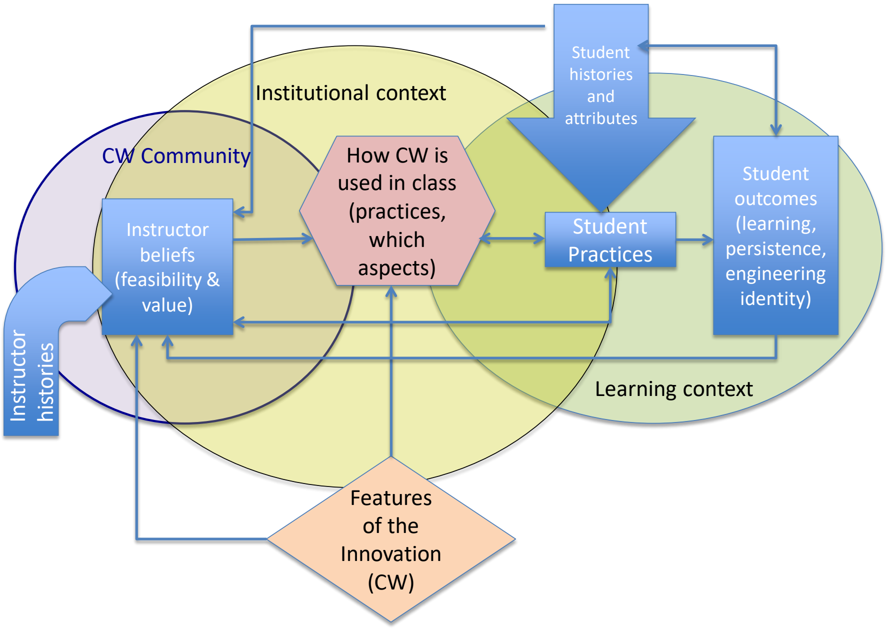


Figure 3. Model of the educational ecosystem for a single institution and where the Concept Warehouse (CW) fits within the ecosystem.

Study Design

As the Concept Warehouse propagates into Mechanical Engineering, we seek to understand how the instructors' use of the Concept Warehouse relates to dimensions of the educational ecosystems. To maximize the range of contexts in the sample, we are studying five diverse institutions: a large public research university, a small private university, a 2-year college serving a large number of under-represented students, a large non-PhD granting public university, and a bilingual public research university. Our design includes initial semi-structured interviews with faculty to understand their contexts and their initial thinking about use of the Concept Warehouse, classroom observation and follow-up interviews for those who try out aspects of the tool in their classes, and focus group interviews with their students. Through the tool we will collect student learning data (Concept Inventories available on the Concept Warehouse) and traces of instructional use by all participating instructors.

Grounded in the model shown in Figure 3, our goal is to understand how instructor decisions, motives and constraints are embedded in the contexts in which they work, and how the strategies adopted relate to student learning in those settings. We also seek to understand the impact of the Concept Warehouse on student outcomes, including concept learning and engagement, with particular attention to interactions between context, practice, and outcome. This approach is an extension of what Freeman et al. (2014) call “second-generation research” that investigates which “type of active learning is most appropriate and efficient for certain topics or student populations” (page 8413).

Preliminary Data

In this paper, we analyze initial interview data from 14 faculty members together with institutional data to illustrate aspects of how educational ecosystems interact with propagation goals. Table 1 shows institutional data collected from the 5 participating institutions. Institutional variations include institution and class size, emphasis on teaching, departmental culture, values related to tenure, and student population. Individual instructors in the participating ME departments include 2 lecturers; 6 assistant, 2 associate and 3 full professors; and a doctoral student. To date, 5 are women, 6 are persons of color. They teach a variety of classes including: statics, dynamics, thermal fluids, and materials science. In addition to position, relevant instructor differences include years of teaching experience, formal professional development history, beliefs about students, current instructional practices and goals.

Initial interviews were conducted via Zoom, audiorecorded and transcribed verbatim. Using ATLAS.ti software, interview transcripts are being content-analyzed, using our theoretical model as a guide and allowing patterns to emerge through coding. Even from these early stages in the project, the researchers have noted influences of the instructors’ ecosystems on their participation in line with our model. For example, recruitment appears smoother in more teaching focused institutions with small class sizes than in research intensive institutions with large class sizes (institutional context). This is compounded by learning communities among instructors in the teaching focused institutions that are absent from the larger institutions (instructor histories and beliefs). However, the tool is built to engage all students in a class and could help instructors in the large classes to a greater extent than those who teach small classes (features of the innovation). Thus, there is a challenge in that instructors in contexts where students may be most likely to benefit are those that have less support and more constraints on taking it up. Instructors who are less familiar with active learning strategies in general, or who lack institutional support or peer models, need more instructional guidance built into the tool itself. Aspects of student culture (e.g., classroom cell phone use, sharing of answers or questions among students) may cause instructors to hesitate before adopting Concept Warehouse technology. More insights should emerge as we follow a subset of interviewees as they dive deeper into Concept Warehouse use.

Implications

Although this is a work in progress, we argue that our findings and the conceptual model that frames our research will ultimately inform attempts to effectively transfer educational research into educational practice and expand participation of groups, institutions, and geographic regions that are underrepresented in STEM disciplines.

Table 1. Institutional Data for Concept Warehouse/IUSE Project

Data Item	Public Comprehensive	Public Research	Public Latinx-serving	Private	2-year College
Total Undergraduate Enrollment	21,037	25,699	12,126	3,597	11,363
Total Graduate Enrollment	775	5,287	1,098	71	0
Engineering Undergraduate Enrollment	6,439	7,826	4,718	678	119
- Percent Female	26.7%	20.2%	26.9%	32.0%	13.0%
- Percent Other Underrepresented	16.5%	10.3%	100.0%	8.0%	66.0%
Engineering Graduate Enrollment	241	1,209	285	13	0
Setting	Small Town	Small Town	Urban	Small Town	Suburban
Engineering Teaching Faculty, Tenure Track	151	191	164	64	1
- Percent Female	17.2%	24.1%	22.6%	26.6%	0.0%
- Percent Other Underrepresented	6.0%	0.0%	91.5%	4.7%	0.0%
Engineering Teaching Faculty, Non-Tenure Track	176	56	3	4	1
Total Teaching Faculty	327	247	167	68	2
Engr Undergraduates / Teaching Faculty	19.7	31.7	28.3	10.0	59.5
Non-Teaching Research Faculty	1	91	1	14	0
Comprehensive Fee (Out of State for Publics)	$38,544	$44,775		$70,654	$21,088
Comprehensive Fee (In State for Publics)	$26,664	$25,845	$22,897		$12,844
Number of Engineering Applicants	19,624	3,805	1,371	2,887	n/a
Percent Engineering Applicants Admitted	23.5%	86.7%	60.2%	30.2%	n/a
Percent Engineering Admits Enrolled	26.9%	36.8%	93.9%	21.4%	n/a
Composite ACT Mid Range	31	26.5	NA	31	n/a
CO-OP Program	Optional	Optional	Optional	None	None
Graduate Research Expenditures	$5.5M	$45.3M	$0	$0	n/a
Research Expenditures / Ph.D. Recipients	NA	$612k	$0	$0	n/a
Classes with fewer than 20 students	16.1%	29.1%	NA	52.0%	43.0%
Classes with 20-49 students	71.4%	50.8%	NA	46.5%	57.0%
Classes with 50 or more students	12.5%	20.1%	NA	1.5%	0.0%
4-year graduation rate	40%	32%	3%	85%	n/a
6-year graduation rate	76%	64%	37%	90%	n/a

Acknowledgements

The authors acknowledge the support provided by the National Science Foundation through grant NSF 1820888 and 1821439. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

References

Cheville, RA., 2019, "Pipeline, Pathway, or Ecosystem – Do Our Metaphors Matter?" Distinguished Lecture, ASEE Annual Conference, Tampa, 2019.Deslauriers, L., E. Schelew, and C. Wieman, *Improved Learning in a Large-Enrollment Physics Class.* Science, 2011. **332**(6031): p. 862-864.

Engeström, Y. (2001). Expansive Learning at Work: Toward an activity theoretical reconceptualization. *Journal of Education and Work*, *14*, 133–156.

Freeman, S., S.L. Eddy, M. McDonough, M.K. Smith, N. Okoroafor, H. Jordt, and M.P. Wenderoth, *Active learning increases student performance in science, engineering, and mathematics.* Proceedings of the National Academy of Sciences of the United States of America, 2014. **111**(23): p. 8410-8415.

Friedrichsen, D. M., Smith, C., & Koretsky, M. D. (2017). Propagation from the start: the spread of a concept-based instructional tool. Educational Technology Research and Development, 65(1), 177-202.

Haak, D.C., J. HilleRisLambers, E. Pitre, and S. Freeman, *Increased Structure and Active Learning Reduce the Achievement Gap in Introductory Biology.* Science, 2011. **332**(6034): p. 1213-1216.

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

Koretsky, M.D., J.L. Falconer, B.J. Brooks, D.M. Gilbuena, D.L. Silverstein, C. Smith, and M. Miletic (2014). The AIChE Concept Warehouse: A Web-Based Tool to Promote Concept-Based Instruction. *Advances in Engineering Education*, 4(1).

Lee, W. C. (2019). Pipelines, pathways, and ecosystems: An argument for participation paradigms. *Journal of Engineering Education*, *108*(1), 8-12.

Lord, S. M., Ohland, M. W., Layton, R. A., & Camacho, M. M. (2019). Beyond pipeline and pathways: Ecosystem metrics. *Journal of Engineering Education*, *108*(1), 32-56.

National Research Council, *Expanding Underrepresented Minority Participation: America's Science and Technology Talent at the Crossroads*. 2011, National Academies Press: Washington, DC.

National Research Council, *Discipline-based Education Research: Understanding and Improving Learning in Undergraduate Science and Engineering*, S.R. Singer, N.R. Nielsen, and H.A. Schweingruber, Editors. 2012: Washington, DC.

Nolen, S., I. Horn, C. Ward, and S. Childers, *Assessment tools as boundary objects in novice teachers' learning.* Cognition and Instruction, 2011. **29**(1): p. 88-122.

Nolen, S., C. Ward, I. Horn, S. Childers, S. Campbell, and K. Mahna, *Motivation development in novice teachers: The development of utility filters*, in *Contemporary motivation research: From global to local perspectives*, M. Wosnitza, et al., Editors. 2009, Hogrefe & Huber: Ashland, OH.

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

Rogers, E.M., *Diffusion of innovations*. 2005, New York: The Free Press.

Borrego, M., J.E. Froyd, and T.S. Hall, *Diffusion of Engineering Education Innovations: A Survey of Awareness and Adoption Rates in US Engineering Departments.* Journal of Engineering Education, 2010. 99(3): p. 185-207.

Henderson, C. and M.H. Dancy, *Physics faculty and educational researchers: Divergent expectations as barriers to the diffusion of innovations.* American Journal of Physics, 2008. 76(1): p. 79-91.

Rogers, E.M., *Diffusion of preventive innovations.* Addictive Behaviors, 2002. 27(6): p. 989-993.

Theobald, E. J., Hill, M. J., Tran, E., Agrawal, S., Arroyo, E. N., Behling, S., ... & Grummer, J. A. (2020). Active learning narrows achievement gaps for underrepresented students in undergraduate science, technology, engineering, and math. *Proceedings of the National Academy of Sciences*, *117*(12), 6476-6483.