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Understanding Context: Propagation and Effectiveness of the Concept Warehouse in Mechanical Engineering at Five Diverse Institutions and Beyond – Results from Year 2

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Brian Self obtained his B.S. and M.S. degrees in Engineering Mechanics from Virginia Tech, and his Ph.D. in Bioengineering from the University of Utah. He worked in the Air Force Research Laboratories before teaching at the U.S. Air Force Academy for seven years. Brian has taught in the Mechanical Engineering Department at Cal Poly, San Luis Obispo since 2006. During the 2011-2012 academic year he participated in a professor exchange, teaching at the Munich University of Applied Sciences. His engineering education interests include collaborating on the Dynamics Concept Inventory, developing model-eliciting activities in mechanical engineering courses, inquiry-based learning in mechanics, and design projects to help promote adapted physical activities. Other professional interests include aviation physiology and biomechanics.

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WIP: Understanding Context: Propagation and Effectiveness of the Concept Warehouse in Mechanical Engineering at Five Diverse Institutions and Beyond – Results from Year 2

It has been well-established that active learning strategies increase student retention, improve engagement and student achievement, and reduce the performance gap of underrepresented students [1], [2]. Concept-based learning is a particular form of active learning which "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" [3], and its effectiveness has also been established [4], [5]. Despite the evidence supporting concept-based instruction, many faculty continue to stress algorithmic problem solving. In fact, the biggest challenge to improving STEM education is not the need to develop more effective instructional practices, but to find ways to get faculty to adopt the evidence-based pedagogies that already exist.

Our project aims to propagate the Concept Warehouse (CW), an online innovation tool that was developed in the Chemical Engineering community [6], into Mechanical Engineering (ME) and other disciplines. A portion of our work focuses on content development in mechanics, and includes statics, dynamics, and to a lesser extent strength of materials. We are also studying how different contexts affect the uptake of the CW within the mechanics community. As discussed last year, our IUSE project objectives are to:

1. Extend the use of the Concept Warehouse (CW) to Mechanical Engineering (ME) and grow by 50,000 student users from diverse populations. To achieve this objective, we will:
   a. Develop content [at least 300 new ConcepTests] for Statics and Dynamics.
   b. Continue development of ME research-based Instructional Tools (e.g., Inquiry-Based Activities and Interactive Virtual Laboratories) that help students develop conceptual understanding.
   c. Serve as a repository for Concept Inventories that can be used by ME (and other) instructors.
   d. Provide extensive learning analytics for users who wish to perform research, test or develop new Concept Inventories or ConcepTests, and/or use them to inform classroom instruction.
2. Investigate the propagation of the CW as it expands into ME, with a specific focus on understanding aspects of the educational systems that influence the propagation of the CW in five diverse institutional settings. Aspects of the educational systems include institutional context; instructor histories, beliefs and practices; student histories and practices; and the affordances and constraints of the technological innovation itself.
3. Conduct educational research on effectiveness of validated instructional practices across five diverse institutions. This research will identify ways to support engagement and conceptual learning of diverse populations of students, within the contexts of the educational systems (i.e., institutional contexts, instructor and student histories, beliefs and practices, and the innovation – the CW).
4. Promote and track propagation of the enhanced CW via targeted community building in ME. This will be accomplished through workshops, implementation of an Action Research Fellows

Program, collaboration with professional societies in ME and outreach efforts to two-year colleges.
5. Continue to develop and refine a sustainability plan for continued expansion of the CW.

Last year, we focused on objectives 1 and 2. This year, we will provide a brief update on our progress on these, and will expand upon objective 4, community building.

Content Development

The Concept Warehouse (https://newjimi.cce.oregonstate.edu/concept_warehouse) is a repository of ConcepTests, Concept Inventories, and Instructional Tools. The majority of the work of our Content Development Teams (CDT) have been developing new ConcepTests. Each team, one for statics and one for dynamics, developed a topic list, and then further broke these topics into subtopics to help organize the content. As we have created more questions, we have targeted topics and subtopics where coverage is lacking. To date, our CDTs (along with others in the community who may have contributed their own questions) have created 285 statics and 381 dynamics ConcepTests.

Additionally, a student researcher at Oregon State University has created four simulations that can be included in Instructional Tools (IT). To date, they have all been beta tested using a Learning Management System, and they have now all been integrated into the Concept Warehouse as part of an IT. Further discussion of this can be found in Cook et al., 2021 [7].

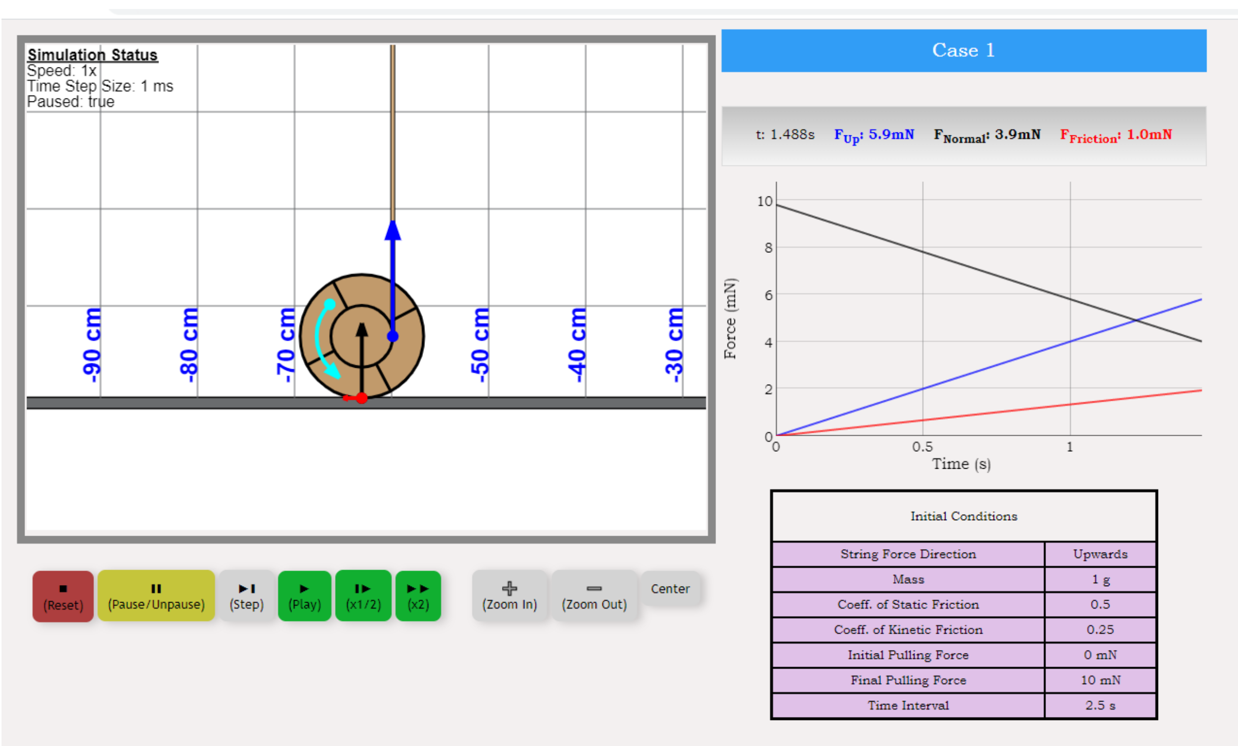

Figure 1. Screenshot of a simulation of Case 1 of the Spool

A screen shot of one of the simulations is provided in Figure 1. A screenshot of the Pulley IBLA and Spool IBLA Instructional Tools is shown in Figure 2.

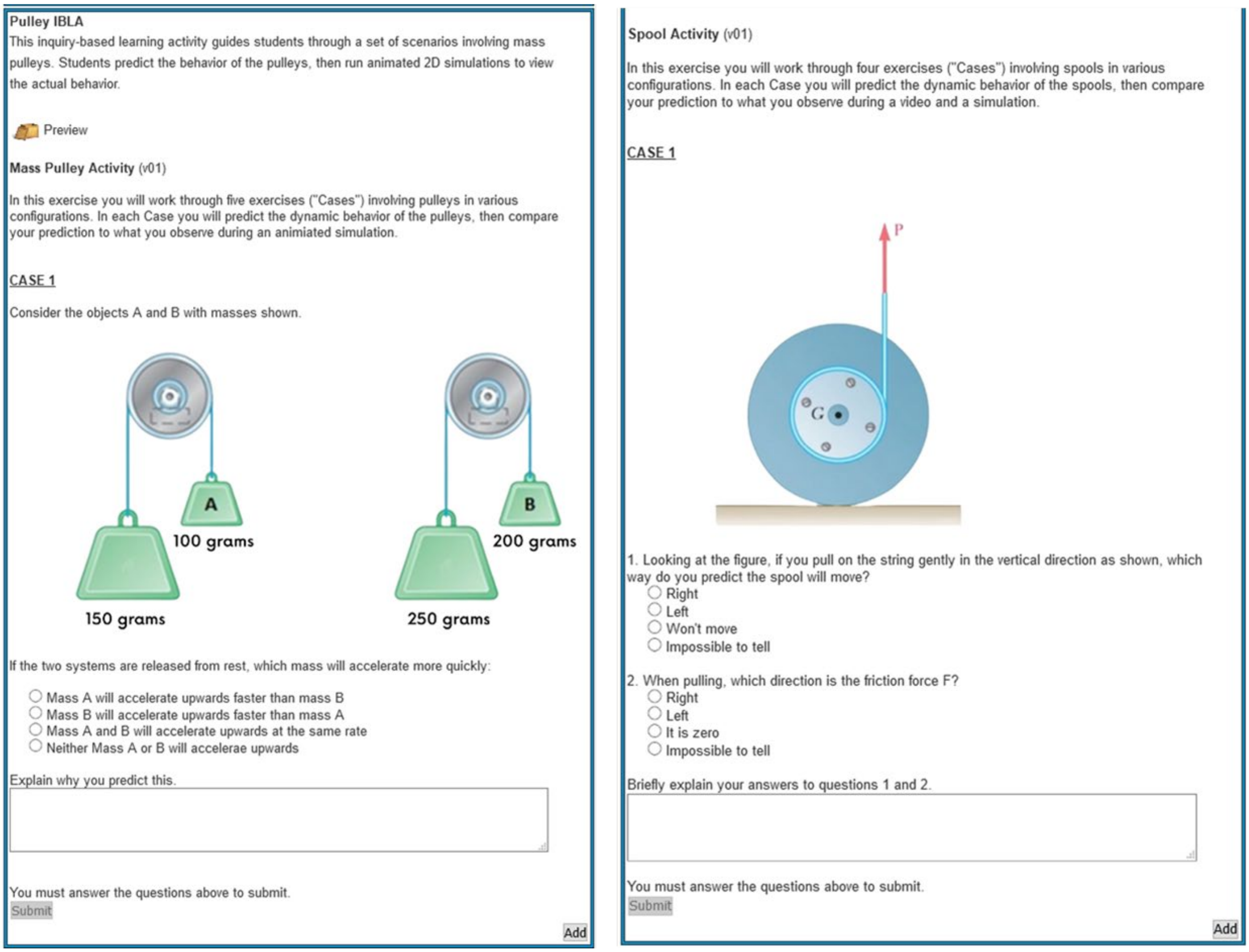

Figure 2. Screenshots of the Pulley IBLA and the Spool Activity.

Community Building

During initial interviews, we found that potential adopters needed coaching on the benefits of concept-based instruction, training on how to use the CW, and support on how to best implement the different affordances offered by the CW. This caused a slight shift in our initial research plans, and much of our recent work has concentrated on using faculty development activities to help us advertise the CW and encourage evidence-based practices. From these activities, we are recruiting participants for surveys and interviews to help us investigate how different contexts affect the adoption of educational innovations. We held a workshop at the 2020 Virtual ASEE conference that attracted over 50 participants. A set of two 4-hour summer workshops attracted over 270 applicants, and over 60 participants attended each synchronous offering. Other applicants were provided links to recordings of the workshop.

From these participants, we recruited 20 instructors to join our Community of Practice (CoP) and had six different meetings over the past year. These members shared how they use the CW in their classes, especially in the virtual environment. The CoP discussed using evidence-based practices, demonstrated different uses of the CW, and suggested potential improvements to the tool, particularly in light of the recent increase in the use of online instruction due to the COVID-19 pandemic. Participants will also be interviewed to help us determine barriers to adoption, how their institutional contexts and individual epistemologies affect adoption, and how they have used the CW in their classes. Our research will help us formulate strategies that others can use when attempting to propagate pedagogical innovations.

A particular topic of focus in the CoP was the use of CW feature to collect written responses from students alongside their direct responses to the ConcepTests. The CW then allows the instructor to view the responses and select representative subsets. This process can be used to identify and respond to specific lines of reasoning, to compare the accuracy of the written response with the itemized response [8], and to promote verbal dialogue, on the basis that students who have already written a response might feel more confident to express their idea publicly.

We had six participants volunteer to be a part of our Action Research Scholars (ARS) Program. These instructors are interested in investigating the efficacy of some aspect of their concept-based instructional practices. Members of our research team are mentoring the ARS in a small group setting to help establish research questions, discuss assessment techniques, and formulate proposals for Institutional Research Board reviews. Participants were required to:

- Meet with the community of scholars and research partners twice per semester.
- Stay in regular communication and attend meetings with the program research partner as needed.
- Work with the program research partner to further develop the proposed study and ensure compliance with all policies of the Institutional Review Board for research on human subjects.
- Document successful completion of two cycles of action research, comprised of (1) formulating research questions related to the CW, (2) collecting data, (3) analyzing data and (4) determining future actions, either teaching or research related, stemming from the data analysis.

Interviews

To date, we have interviewed 24 different instructors who have had some type of experience with the Concept Warehouse. Seven of these participants have participated in our Community of Practice and have been interviewed twice. We are currently transcribing these interviews and will analyze them to determine what contexts encourage (or possibly discourage) faculty use.

One example of some of the effects of the CoP is shown in one of the interview responses:

> *I guess I'll just say, I think for me, I think it's shown me how powerful asking those conceptual questions can be. And I think it's definitely made me value them more on the assessment side, so I think that's a good thing. And then I think the other thing that's really valuable is, it's easy for those questions because, they're quick to turn into then introspection or conversation for the students. And I think that's really valuable.*

Conclusions

Our diverse, multi-institutional team is studying how context affects the uptake and use of an online educational tool, the Concept Warehouse. To date, our team has developed over 600 statics and dynamics concept questions and is in the process of creating instructional tools for the use in these mechanics courses. We have begun to disseminate our work through workshops (e.g., NETI, ASEE section meetings, the ASEE National meeting, CW workshops), and have recruited six participants in our Action Research Fellows program. By studying the context in which instructors adopt and utilize the CW, we will be able to provide recommendations for encouraging use of the CW and of other pedagogical innovations.

Acknowledgments

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References

[1] S. Freeman, 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," *Proc. Natl. Acad. Sci.*, vol. 111, no. 23, pp. 8410–8415, 2014, doi: 10.1073/pnas.1319030111.

[2] M. J. Prince, "Does Active Learning Work? A Review of the Research," *J. Eng. Educ.*, vol. 93, no. 3, pp. 223–231, 2004, doi: 10.1002/j.2168-9830.2004.tb00809.x.

[3] M. Koretsky, S. Nolen, B. Self, C. Papadopoulos, J. Widmann, M. Prince, and D. Dal Bello, "for Systematic Development of Conceptests for Active Learning," in *Proceedings EDULEARN 19 (11th Annual International Conference on Education and New Learning Technologies)*, 2019, vol. 1, pp. 8882–8892. doi: 10.21125/edulearn.2019.2205.

[4] R. R. Hake, "Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses," *Am. J. Phys.*, vol. 66, no. 1, pp. 64–74, 1998, doi: 10.1119/1.18809.

[5] D. C. Haak, J. HilleRisLambers, E. Pitre, and S. Freeman, “Increased Structure and Active Learning Reduce the Achievement Gap in Introductory Biology,” *Science (80-.).*, vol. 332, no. 6034, pp. 1213–1216, 2011, doi: 10.1126/science.1204820.

[6] M. D. Koretsky, J. L. Falconer, B. J. Brooks, D. M. Gilbuena, D. L. Silverstein, C. Smith, and M. Miletic, “The AiChE Concept warehouse: A web-Based tool to Promote Concept-Based instruction,” 2014. Accessed: May 31, 2021. [Online]. Available: https://eric.ed.gov/?id=EJ1076138

[7] J. Cook, T. Ekstedt, B. P. Self, and M. D. Koretsky, “Work-in-Progress: Computer Simulations to Deliver Inquiry-Based Laboratory Activities in Mechanics,” 2021.

[8] M. D. Koretsky, B. J. Brooks, R. M. White, and A. S. Bowen, “Querying the Questions: Student Responses and Reasoning in an Active Learning Class,” *J. Eng. Educ.*, vol. 105, no. 2, pp. 219–244, Apr. 2016, doi: 10.1002/jee.20116.