Applying learning science findings to instruction

The following document summarizes several researched-based findings that have been shown to facilitate student learning and are useful for in-class and online learning. You can use this document to generate ideas for incorporating research-based learning and teaching practices into your MITx grant proposal. For each finding, a key reference is provided for further reading. At the end of the document, you will find two instructional design frameworks that incorporate many of these findings.

RESEARCH-BASED FINDINGS

Retrieval practice (the "testing effect")

Description: The ability to recall and remember knowledge increases if it is periodically retrieved. The act of retrieval solidifies learning, particularly when feedback is provided.

Implications: Administer low-stakes quizzes frequently. Encourage students to test their understanding and remind them that the act of testing themselves not only allows them to know what they don't know, but enhances their ability to retain what they do know.

- Roediger, H. L., & Butler, A. C. (2011). The critical role of retrieval practice in long-term retention. *Trends in Cognitive Sciences*, 15(1), 20–27. http://doi.org/10.1016/j.tics.2010.09.003

Spaced and interleaved practice

Description: Spacing out repetition is more effective for learning than is studying an idea over a single period (even if it is longer than each of the many repetitions). Interleaving the practice of problems types results in greater learning gains than asking students to do the same type of problem over and over (mass practice). Interleaving increases student's ability to discriminate between different problem types.

Implications: Space how often content/concepts are reviewed or recalled across weeks and months. Administer cumulative problem sets and exams throughout the semester. Review concepts covered in previous class periods/modules at the beginning of class. Rearrange the order of practice problems in problem sets and exams as opposed to ordering problems by type.

- Roediger, H. L., & Pyc, M. A. (2012). Inexpensive techniques to improve education: Applying cognitive psychology to enhance educational practice. *Journal of Applied Research in Memory and Cognition*, *1*(4), 242–248. Retrieved from: http://psych.wustl.edu/memory/Roddy%20article%20PDF's/Roediger%20&%20Pyc%20(2012)a_MemCog.pdf

Worked and faded examples

Description: When non-experts are learning new concepts, it is more effective for them to study solutions to solved problems than to attempt solving problems. Worked examples are effective only when learners self-explain the solutions and when multiple, varied worked examples of the same concept are provided. Worked examples apply to non-experts, but not to experts who benefit more from attempting to solve problems than from studying worked examples.

Implications: Provide learners fully worked examples and require them to self explain solutions through asking students follow-up questions (ex: 'Why was this strategy used?', 'What principle is being applied and why?'), annotating solutions, identifying an error in a solution or asking students to compare solutions of two contrasting examples. As leaners become more expert, fade support by asking students to attempt solving subsequently more and more steps within a problem.

- Renkel, A. (2014). Learning From Worked Examples: How to Prepare Students for Meaningful Problem Solving In V. A. Benassi, C. E. Overson, & C. M. Hakala (Eds.). *Applying science of learning in education: Infusing psychological science into the curriculum*. Retrieved from the Society for the Teaching of Psychology web site: http://teachpsych.org/ebooks/asle2014/index.php

Active learning

Description: Instruction that requires students to engage cognitively and meaningfully with content results in better learning than instruction where students are solely exposed to information passively. Although effective active learning does not require peer-to-peer interactions, activities that deeply engage students in co-generating answers seem to yield the greatest learning gains.

Implications: In class, administer activities that ask students to apply the information presented. Provide opportunities for students to engage cognitively with each other through the use of collaboration and community tools such as collaborative annotators. While demonstrating or providing worked examples, ask probing questions that require explanation of solution steps (see section on 'Worked and faded examples').

- Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H., & Wenderoth, M. P. (2014). Active learning increases student performance in science, engineering, and mathematics. *Proceedings of the National Academy of Sciences*, 111(23), 8410–8415. http://doi.org/10.1073/pnas.1319030111

Pre-/Post-testing

Description: Assessing understanding of the most important concepts and tasks in a course at the beginning and end of the course, allows instructors to determine what students know when they start the course and how much they learned in the course. Students' prior knowledge could be correct, incomplete and/or faulty. If prior knowledge is faulty (misconceptions) students might resist or ignore new information that conflicts with it. Pre-/post-testing also allows instructors to determine what misconceptions students come with and how much conceptual change happens as a result of the course.

Implications: Design and administer the same test at the beginning and end of a module or course. Include questions that will surface common misconceptions students have on the content covered.

- Adams, W. K., & Wieman, C. E. (2011). Development and Validation of Instruments to Measure Learning of Expert-Like Thinking. *International Journal of Science Education*, *33*(9), 1289–1312. http://doi.org/10.1080/09500693.2010.512369

INSTRUCTIONAL FRAMEWORKS

First principles of instruction:

David Merrill synthesized the key principles common among leading instructional design frameworks. Namely, learning is promoted when 1) learners solve real-world problems, 2) existing knowledge is activated as a foundation for new knowledge, 3) new knowledge is demonstrated to the learner, 3) new knowledge is applied by the leaner, with feedback and 5) new knowledge is integrated into the leaner's world, providing a foundation for future learning.

- Merrill, M. D. (2002). First principles of instruction. *Educational Technology Research and Development*, 50(3), 43–59. http://doi.org/10.1007/BF02505024

Four-component instructional design (4C/ID):

The 4C/ID model is a specific framework, consistent with David Merrill's principles (see 'First principles of instruction'), and based on research on the limitations of working memory (cognitive load theory). Instructional blue prints are described using four basic components: 1) tasks, 2) supportive information, 3) procedural information and 4) part-task practice.

- van Merrienboer, J. J. G., Clark, R. E., & De Croock, M. B. M. (2002). Blueprints for complex learning: The 4C/ID-model. *Educational Technology Research and Development*, 50(2), 39–64. http://doi.org/10.1007/BF02504993

For questions on research findings and/or instructional frameworks, please contact the Residential Education team in the Office of Digital Learning:

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