Using the FaCT System (Fact and Concept Training System) for Classroom and Laboratory Experiments

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The FaCT system offers a general platform for using a quantitative model of cognition to schedule practice of simple information. In this system, practice is selected for items in a set of items to be learned to maximize the long-term learning gain relative to the time cost of learning as predicted by the model. This instructional system allows web deployment of structurally simple content such as paired-associates and exemplar based practice of inference rules (practice of items that are examples of the application of a rule that can be inferred). On the student side, this practice is similar to flashcards, where each practice trial presents some cue and expects some response; however, the order and frequency of flashcard presentation is controlled by the model predictions. While the system can be used to create traditional laboratory experiments or quizzes online quickly and easily, it was principally designed to provide a general platform for delivering adaptive practice according to the predictions of a computational model that tracks student performance. The FaCT system (http://optimallearning.org) is an independently funded educational technology that is being used in some of the Pittsburgh Science of Learning Center's (PSLC) experimental and classroom (LearnLab) research projects.

This sort of optimal practice system is useful because many complex domains of study require some collection of basic facts that form the basis of the complex procedures of the domain. For example, it is clear that basic arithmetic facts must be mastered by an individual if they desire to learn more complex mathematical skills such as fractional arithmetic or algebra. Without these facts even the most simple work at these higher levels of the mathematical domain become extremely time consuming even assuming an individual might have access to a calculator. This is increasingly recognized by authorities and the new Curriculum Focal Points document by the National Council of Teachers of Mathematics stresses the importance of these basic facts (National Council of Teachers of Mathematics, 2006).

The default FaCT system algorithms for drill practice delivery (test trials followed by review in the case of failure) were initially developed as part of the dissertation research of Pavlik Jr. (Pavlik Jr. & Anderson, 2005, accepted; Pavlik Jr. et al., 2007). In this research, Pavlik showed that it was possible to use a cognitive model to determine an optimal balance between the long-term retention benefits of wider spacing of practice and the practice speed advantage of more narrowly spaced practice. This work is in contrast to most attempts to find the optimal schedule of practice which have not attended to the time on task differences between different practice schedules (e.g. Cull, 2000).

The workshop will be organized as follows:

1. Introduction (25 minutes)
    a. Background and examples
    b. System vocabulary – pass out copies of draft manual
2. Content search (25 minutes)
    a. Find lists of stimuli online / Bring your own stimuli

    b. Put lists in proper format
3. Create model-controlled session (20 minutes)
    a. Create training system at online creation website
    b. Test training system
    c. Navigate to and download training definition file
4. Modify model-controlled sessions (30 minutes)
    a. How do the learning sessions work?
    b. Make simple modifications to training parameters
    c. Test the modifications
    d. How can the model be changed and the parameters be found from data?
5. Create quiz/experiment session (40 minutes)
    a. Creating randomized patterned schedules (tests or quizzes)
    b. Test quiz/experiment

The introduction section will be a sequence of PowerPoint slides, providing background on the research behind the system and examples of the high-level capabilities of the system. The FaCT system implements the memory performance prediction equations from the ACT-R (Adaptive Character of Thought - Rational) cognitive model (Anderson & Lebiere, 1998; Pavlik Jr. & Anderson, 2005). Unlike cognitive tutors produced as part of the PSLC Cognitive Tutor Authoring Tools (CTAT) project, which are based on ACT-R's production system architecture, the memory equations in ACT-R are a math model that provides predictions of performance based on the history of practice for an item. While other quantitative models can be substituted or compared in the system, the ACT-R memory equations work well because they have been found to fit complex schedules of practice over multiple timescales. The system uses this model by default to track student performance (capturing practice effects such as frequency, recency, spacing, and testing effects) and decide the best item to practice next.

Following this introduction, students will write or find appropriate content for their training systems. Students will be free during this time to surf the internet and cut and paste some list of content items they want to learn from its source into a text editor. Alternatively, participants could type in a simple list or use their own preexisting content. After finding or creating the lists participants will be instructed in how to put the information into the tab delimited format required for input into the system.

Once stimuli are gathered, participants will go to the training system creation website and upload their stimuli files. The webpage will automatically create the required files on the server and tell users the web URL for their new training system. Participants will go to this URL and test their training system for a few minutes of practice. Participants will be asked to note any problem with how their training system functions and given tips on effective testing. After this testing, participants will download the controller file (the Training Definition File or TDF).

For the fourth part of the workshop, participants will have the opportunity to "get under the hood" and modify the behavior of their training system (this portion will not require programming experience, but college algebra and very basic calculus will be needed to fully understand the explanations). To do this, participants will be instructed in how the practice schedule the training system produces depends on a cognitive model's predictions. This discussion will include a high-level description of what the model's parameters mean in terms of capturing practice and retention effects. For example, an *a* parameter captures the baseline forgetting rate, while *c* captures how much the forgetting rate increases as practice spacing becomes more narrow. In this case, these two parameters allow the model to capture the spacing-by-retention-interval interaction and manipulating them may either increase of decrease the importance of spaced practice in the model, which helps fit the pattern of trial selection to the needs of the task being trained. Participants will then have the opportunity to change parameters of their training system and directly observe the results.

The fourth section will continue by describing how parameters can be determined empirically through fitting the model to a prior dataset. This half of the section will be in the form of demonstration, where we show how the main program code can be used to run a simple script file that maximizes the log likelihood of the data given the model, giving a general idea of the fit of the parameters, and also puts the data into a MySQL database. Students will be given copies of this model fitting and MySQL dump code which they can use after the workshop to fit and output data. Continuing with the demonstration, participants will be shown how the system permits even greater flexibility due to the Java-based model plug-in architecture, which allows users to change the model to suit their needs (or substitute a different practice model).

During the fifth portion of the workshop, participants will be shown how the system can be used to generate online quizzes and non-adaptive experiments. Participants will be shown the syntax for specifying quiz/experiment sessions and will have the opportunity to create a short quiz using the same stimuli they used for the model-controlled sessions. The FaCT system permits remarkable flexibility in quiz/experiment creation. Using a template system that randomizes both at the level of the item and at the level of the template, templates with specific schedules can be randomly interleaved into template slots in a master schedule. This master schedule can then be subsequently randomized to further counterbalance and control for order effects. Also, quizzes/experiments can have multiple blocks, which permits further flexibility, because blocks can be preceded by instruction screens, an N-back task module that provides a working memory measure, or short survey sessions.

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References

Anderson, J. R., & Lebiere, C. (1998). *The atomic components of thought*. Mahwah, NJ, US: Lawrence Erlbaum Associates Publishers.

Cull, W. L. (2000). Untangling the benefits of multiple study opportunities and repeated testing for cued recall. *Applied Cognitive Psychology, 14*(3), 215-235.

National Council of Teachers of Mathematics. (2006). *Curriculum focal points for prekindergarten through grade 8 mathematics: a quest for coherence*. Reston, VA: NCTM.

Pavlik Jr., P. I., & Anderson, J. R. (2005). Practice and forgetting effects on vocabulary memory: An activation-based model of the spacing effect. *Cognitive Science, 29*(4), 559-586.

Pavlik Jr., P. I., & Anderson, J. R. (accepted). Using a model to compute the optimal schedule of practice. *Journal of Experimental Psychology: Applied*.

Pavlik Jr., P. I., Presson, N., Dozzi, G., Wu, S.-m., MacWhinney, B., & Koedinger, K. R. (2007). The FaCT (Fact and Concept Training) System: A new tool linking cognitive science with educators. In D. McNamara & G. Trafton (Eds.), *Proceedings of the Twenty-Ninth Annual Conference of the Cognitive Science Society* (pp. 397-402). Mahwah, NJ: Lawrence Erlbaum.