Feature

Practice Makes Perfect

Assessing and Enhancing Knowledge and Problem-Solving Skills with IMMEX Software

By Jennifer Underdahl, Joycelyn Palacio-Cayetano, and Ron Stevens

Subject: All

Audience: Teachers, technology coordinators, teacher educators, library/media specialists

Grade Level: K–12 (Ages 5–18)

Technology: Internet/Web

Standards: *NETS•S* 6. *NETS•T* III, IV. (Read more about the NETS Project at www.iste.org—select Standards Projects.)

Most athletes, dancers, and performers spend many hours reviewing tape or at a mirror, scrutinizing every move and gesture so that their perspective is objective and their next swing, step, or scene informed. By continually refining their techniques and developing new maneuvers to enhance their graceful, efficient, and expert routines, strong performers know that reflection is the key to improvement. The same applies to good classroom practices when teachers intuitively and repeatedly pose probing questions into the "how" and "why" of the subject material.

Recently, educators have been searching for ways to sustain their role as effective cognitive coaches as their class sizes burgeon to 30-plus students and as pressure mounts to improve standardized test scores. Administrators, parents, and politicians are counting on technology to deliver teachers into a new age of assessment and instruction; a digital panacea that will revolutionize how students acquire, retain, and apply information from the classroom to testing situations and, ultimately, to our complex and competitive world.

To prepare the next generation with problem-solving skills and the information resiliency needed to accomplish this, teachers will benefit from technology that doesn't simply present new mediums for old learning models, or programs that promote technology for technology's sake, but instead by integrating innovations that will redefine instructional approaches and methodologies. Unfortunately most programs and most software are not flexible or dynamic enough to provide for this level of implementation.

But what if a technology could reinforce and provide acute assessment measures for students' content understanding and problem-solving skills by integrating both into real-world problem scenarios? What if a teacher were able to download and analyze a mirror-image map of each student's thinking processes in one-twentieth the time it takes to read a lab report? Then, from this map, what if this teacher could identify exactly where a student is failing to understand and integrate content into effective problem-solving strategies so that scaffolding approaches would be meaningful and appropriate?

Learn how teachers of all grade levels and disciplines can use this technology-based assessment tool that integrates and maps their students' abilities to analyze, synthesize, test, and apply information to real-world problems.

Figure 1. A True Roots problem-solving prologue.

And if this tool allowed teachers to write new and/or arrange existing problem sets to precisely fit their curricular needs? Then even the most persnickety of teachers could use this authorable, flexible, formative assessment tool that engages students, shaves hours off paper grading, assuages any pressure to structure curriculum to align with ISTE's National Educational Technology Standards (NETS), and reflects the fast-paced, digital world in which we live.

Turning to Technology

The IMMEX (Interactive Multimedia Exercises) Project at UCLA (www.immex.ucla.edu) has developed a Web-based assessment program to complement and enhance traditional teaching methods. It trains teachers on authoring and implementation in a time-saving and effective way. The IMMEX design supports the theory that knowledge and complex learning should be dynamic, continuously analyzed, synthesized, tested, and applied to relevant, concrete, real-world issues, so that information is not just quickly memorized and then forgotten while the Scantron is passed to the left (Frampton, 1994). By integrating content understanding into real-world scenarios, the IMMEX problem space helps teachers evaluate and formatively assess student problem-solving performance, concept acquisition, and the growth of both over time.

An IMMEX case poses a scenario that challenges students to investigate the who, what, where, when, why, or how of a problem. Resources are then provided for students to develop, test, and refine hypotheses as they engage in arriving at complex solutions. With this format, IMMEX cases inherit much of the theory of case-based reasoning and goal-directed searches; instructional paradigms that have repeatedly demonstrated significant improvement in student problem-solving performances when practiced in a variety of instances (Branting & Aha, 1995).

Every 10th-grade biology teacher must deliver lessons and orchestrate hands-on activities that address Mendelian principles of inheritance (dominance, recessiveness, and co-dominance), an understanding of blood types and fingerprints, and how to conduct DNA fingerprinting, analyze pedigree charts, and differentiate phenotypes from genotypes. Traditionally, assessing student understanding of these concepts was, if not entirely summative, incredibly time consuming.

"True Roots" (Figure 1) is an IMMEX problem designed and created by a team of biology teachers to assess student understanding of these concepts. In the problem, students are introduced to digital avatar Leucine, who fears that she is a victim of "baby swapping" at birth and begins to conduct a genetic investigation to discover which of five sets of possible parents are truly hers. The students can order tests for blood type, DNA prints, karyotype, fingerprints, and pedigree charts for both Leucine and each set of parents. For students new to this process, the IMMEX environment also provides resource guides and expert advice enabling students to confirm or reevaluate their interpretation. But, because the IMMEX menu structure keeps score to encourage efficiency, using these items requires students to weigh cost versus benefit, decisions that students hotly debate when they work in teams trying to achieve a high score.

Using their understanding of inheritance, students test sets of parents based on the possibility of genetic information being transferred to Leucine and begin to arrive at a solution (Palacio-Cayetano, 1997). There is no predetermined strategy for the students to follow, so there are many pathways they can and do take to arrive at the answer. This freedom to navigate data and to form a strategy provides the teacher a great deal of information about students' problem-solving strengths and weaknesses and about their understanding of the content (Vendlinski & Stevens, 2000).

The IMMEX Case Model

Unlike many traditional pencil-and-paper evaluations that demonstrate only *whether* the student answered correctly, IMMEX shows *how* the student arrived at an answer by literally mapping out which information was examined (the color-coded rectangles), the sequence of the selections (indicated by the line traveling from the middle of the box to the upper-left corner), and how much time was spent in each category (indicated by the color-coded proportional time scale at the top of the page). From these diagrams, also known as *search path maps*, a teacher can quickly see where students are having difficulty with content or problem solving, where they are succeeding, and, ultimately, the quantifiable growth of their problem-solving skills and content retention over time. Figure 2 shows a student's performance demonstrating not only content understanding and synthesis but also an efficient elimination strategy. IMMEX provides immediate and objective results for both teachers and students, making for interventions that are appropriate and formative.

Figure 2. An example of a True Roots search path map demonstrating high content understanding and application as well as an efficient problem-solving strategy.

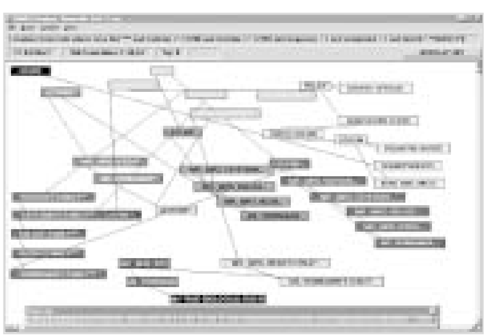

Figure 3a. A first attempt that demonstrates a student's problem environment discovery: random selection of information and collection of nearly all data. Student looked at 39 menu items and took 34 minutes to solve.

Figure 3b. A second attempt by the same student shows immediate refinement of strategy: the sequence is more logical and efficient. This time the student looked at 19 menu items and took 10 minutes to solve.

When IMMEX cases are written, many variations or "clones" of each case are created that maintain the integrity of the problem structure but alter the embedded information, so that each time through the problem space, the answer is different. For example, the information from the first case of True Roots will lead students to correctly choose the Watsons as Leucine's parents. On their second attempt at True Roots, students find the information will lead them to one of the remaining four sets. Because the computer randomly selects the order of the cases, and because some of the problems have as many as 60 cases, the unwanted sharing of information among students is greatly decreased. These collections of similar cases are called *problem sets* and allow students to view and interact with the system from many different perspectives.

When first introduced to a new problem set, most students tend to open every menu item to become familiar with the types of information and how the problem environment is structured. This sort of investigation usually takes True Roots testers 25–35 minutes to gather and solve. The second time through the same problem set, they begin to develop a more integrated view of the embedded content and an appreciation for what is relevant (Figure 3a). As a result, strategies become more refined, and the time to solve a case begins to lessen for the majority of students (Figure 3b). By the fourth or fifth try, a True Roots case can be solved in 10 minutes or less.

Strategy Groups

As a starting point for tracking student progress, teachers, educators, and researchers are developing scoring rubrics to help cluster performances into strategy groups. A True Roots tester would be evaluated and ranked by his or her ability to develop an elimination strategy, reduce redundant data and resource usage, advice, and conjecture. As students solve a series of problems, these strategy groups and the performance transitions among them result in state transition diagrams that can identify different types of difficulties students face while solving these problems. Eventually these diagrams may help document the effects different interventions have on student problem-solving progress.

For instance, for True Roots, student performances fall into five general categories:

1. *Significantly Below Standard*—randomly accesses test or library items, spends majority of time in reference section, unable to clearly interpret problem query, and unable to explain logic. These students tend to guess (Figure 4).
2. *Below Standard*—can extract problem query, show excessive data/test usage, inability to interpret data/test, has no elimination strategy, and marginally able to explain logic (Figure 5).
3. *Just Below Standard*—elimination strategy occasionally used, does not always distinguish relevant from irrelevant data, premature problem closure, reliance on conjecture/advice, unable to interpret some data, and shows some ability to explain selections and connections (Figure 6).
4. *Standard*—distinguishes relevant and irrelevant data, elimination strategy used, generally interprets data correctly, effective use of library, able to provide a general account of the logic used to solve (Figure 7).
5. *Above Standard*—elimination strategy and data reduction, frequently interprets data correctly, recognizes essential data, able to explain how evidence connects, and able to provide a detailed account of logic required (Figure 8).

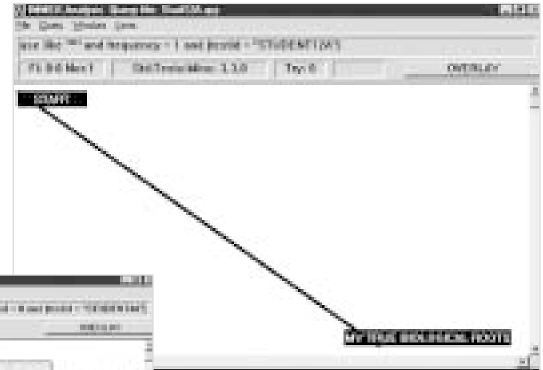

Figure 4. Significantly Below Standard.

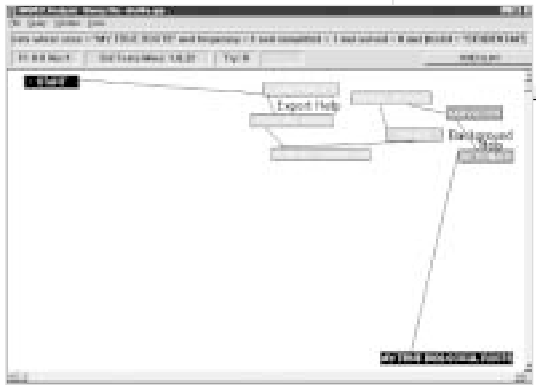

Figure 5. Below Standard.

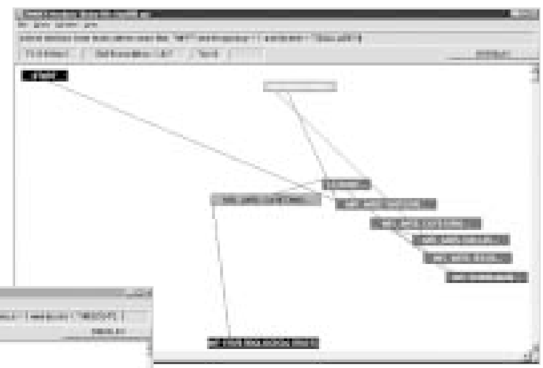

Figure 6. Just Below Standard.

Figure 7. Standard.

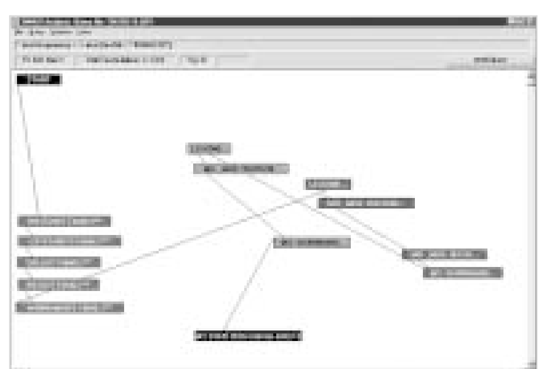

Figure 8. Above Standard.

Examining performances on multiple problems within the problem set shows that few students break out of the Below Standard categories on their own. Some students using a Just Below Standard strategy (viewing much more information than needed to solve the problem) naturally advance to a more effective strategy, suggesting their initial exploration was to familiarize themselves with the entirety of the available information.

However, students who start at Just Below Standard and don't quickly make this jump seem to become locked into this particular approach. Thus, it is important for teachers to identify the effective data trends so that through appropriate intervention, they can support each student toward reaching his or her potential. IMMEX research efforts incorporate artificial neural networks—programs that cluster large numbers of student performances—to automate this process so that teachers can gather assessment information quickly (Vendlinski & Stevens, 2000).

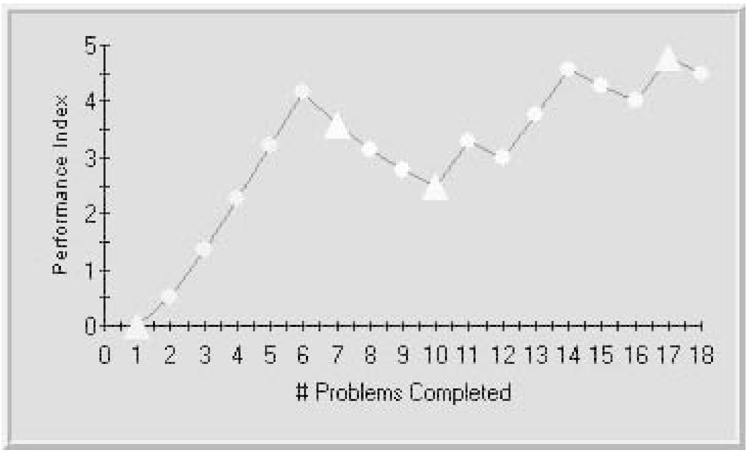

Figure 9a. A student having difficulty.

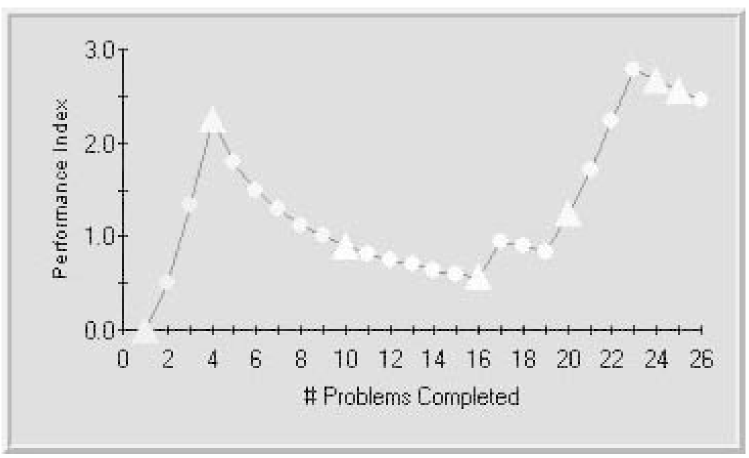

Figure 9b. A student showing irregular progress.

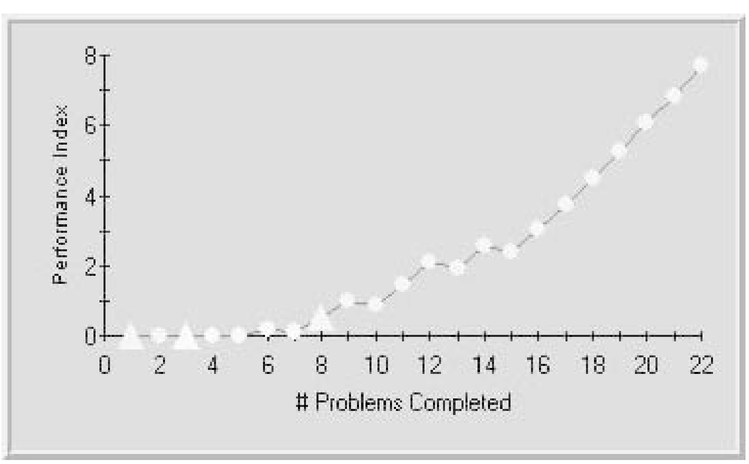

Figure 9c. A student showing progress after a slow start.

A Web Presence

Technology integration in the classroom can be daunting and complex, and not necessarily what all teachers wish to tackle (McNally & Etchison, 2000). Fortunately, IMMEX on the Web also provides student progress measures that are immediate and easy to read. IMMEX calculates progress by charting, in step-by-step detail, the cases each student has performed and solved. Teachers can retrieve the search path maps of every performance for each student. IMMEX also provides breakdowns of overall class performance progress, the aggregate class performance on each problem set, distribution charts of those scores, and a class-by-class list of individual student Performance Index (PI) scores, which are calculated by plotting the number of problems solved against the percentage solved. The PI over a problem set provides an accurate representation of how well a student understands a particular topic covered by an IMMEX problem and allows a teacher to follow student problem-solving progress over time. It also provides researchers a number to correlate to other student achievement indicators, such as standardized tests, grade point averages, and Advanced Placement exams. Figures 9a–9c show at-a-glance progress indicators that plot the number of IMMEX problems completed by a student to the PI of that student after each performance.

Practice Makes Perfect

Every teacher pummeled you with that mantra, every coach taunted you with it, and the first time you used it on your own students, you instantly became one of "them"—suddenly more right than you had ever wanted to believe. IMMEX research suggests that they were right, too. Data from nearly 300 students repeatedly shows that problem-solving skills improve with practice over time (Figure 10). Extensive data analysis from many performances also has shown that a student's PI correlates significantly with Advanced Placement exam predictability, STAR Math and Science exams, multiple-choice exams, and composite grades, suggesting that any pedagogy that reinforces problem-solving practice will have a positive effect on standardized test scores.

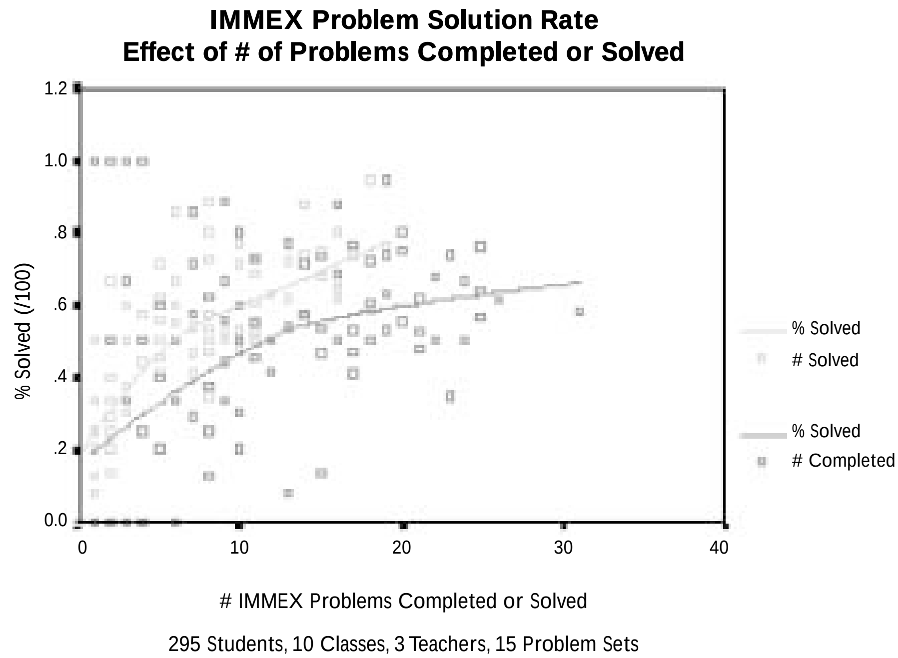

Figure 10. This graph compares the number of IMMEX problems 295 students completed (dark gray) or solved (light gray) to the percentage of those same problems that the students solved. Fitted logistic regressions curves indicate how student experience improves asymptotically over time.

To Learn More

For five years, the IMMEX staff has conducted professional development workshops training teachers how to integrate curriculum into technology by building problem sets for classroom use. Teachers have authored more than 500 problem sets, which are being used in more than 200 schools nationwide, that align with national and state standards and span multiple grade levels and disciplines. Because the problem sets are malleable, teachers decide what to keep, to toss, and to rewrite, so that they can acutely assess student understanding of specific content. Through assessment with IMMEX feedback, which is formative in nature, new models for learning, retention, and transfer are being developed.

To learn more about IMMEX, to search for problem sets that may fit your curricular needs, or to find out more about professional development opportunities, go to www.immex.ucla.edu and "get started."

References

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