Leveraging Cognitive Theory to Create Large-Scale Learning Tools

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OUTLINE

Call to Action

Automated Item Generation

Examples

Discussion
OVERVIEW - WHY

Figure 1: Ed Dubinsky
THEORETICAL RESPONSES TO CHALLENGE

- Include practitioners in conferences.
- Include instructors in research projects (e.g., NSF Grant 1624970)
- Summarize/disseminate research results in ready-to-use formats (e.g., Carlson, Oehrtman, & Engelke, 2010; NSF Grant 1821553).
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We want to focus on the ready-to-use assessments.
**Why focus on assessment?**

**Figure 2:** Simplistic model of how assessment can affect instruction in classrooms.
Multiple-Choice Assessment
MULTIPLE-CHOICE ASSESSMENT
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Concept Inventory

Multiple-choice assessments designed to explore students’ conceptual knowledge of a specific topic.

Precalculus Concept Inventory development:

I & II  Open-ended questions to identify and analyze student conceptions.

III  Validation of multiple-choice questions based on Phases I & II.

IV  Widespread administration of revised 25 item multiple-choice assessment.
Leveraging Technology

Overarching Goal: To utilize the open-ended questions and insights gained from RUME research to generate multiple-choice assessments that can be used as learning tools.
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Figure 3: Illustration of AIG terms.

Solve the linear equation below.

\[
\frac{-3x - 6}{3} - \frac{-8x - 8}{5} = \frac{7x + 6}{2}
\]

[Options]

A. \( x = -\frac{40}{29} \) [Distractor]

B. \( x = -\frac{34}{29} \) [Solution]

C. \( x = -\frac{66}{29} \) [Distractor]

D. \( x = -\frac{17}{10} \) [Distractor]
GENERATING DISTRACTORS

Methods to generate multiple-choice item distractors:

- Generate based on similarities to the solution
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Theoretically, automated item generation should be able to generate distractors using any of the methods above.
Example

Dubinsky and Wilson (2013)

1. Suppose $f$ and $g$ are two functions. Find the compositions $f \circ g$ and $g \circ f$.

2. Suppose $h = f \circ g$ is the composition of two functions $f$ and $g$. Given $h$ and $g$, find $f$.

3. Suppose $h = f \circ g$ is the composition of two functions $f$ and $g$. Given $h$ and $f$, find $g$. (Dubinsky & Wilson, 2013, p. 97)
In both the written instrument and the interviews, we asked students questions, some of which we considered to be difficult, about composition of functions. Our intention was to investigate the depth of their understanding of the function. We also felt that success in solving these problems was an indication of a process conception of function and in some cases, an indication of a process conception that was strong enough so that it could be reversed in the mind of a participant in order to solve a difficult composition problem (pgs. 96-97).
AIG Example - Question Type 1

Specific: Suppose \( f(x) = (x + 1)^2 \) and \( g(x) = \frac{1}{3}x^2 \) are two functions. Find the composition \( (f \circ g)(x) \) at the point \( x = 5 \).

A. \( \frac{784}{9} \)
B. 300
C. \( \frac{1296}{3} \)

Generalized: Suppose \( f(x) = (x + c)^2 \) and \( g(x) = \frac{b_1}{b_2}x^2 \) are two functions. Find the composition \( (f \circ g)(x) \) at the point \( x = a \).

A. \( f(g(a)) = \left(\frac{b_1}{b_2}a + c\right)^2 \)
B. \( (f \cdot g)(a) = \frac{b_1}{b_2}a^2 (a + c)^2 \)
C. \( g(f(a)) = \frac{b_1}{b_2} (a + c)^4 \)

Figure 4: Dynamically generating a procedural composition of functions question.
AIG Example - Question Type 2

Specific: Given only the information in the following table, find $f(2)$ (if possible).

<table>
<thead>
<tr>
<th>$x$</th>
<th>$h(x)$</th>
<th>$g(x)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>1</td>
<td>-3</td>
</tr>
<tr>
<td>-3</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>-2</td>
<td>0</td>
<td>2</td>
</tr>
</tbody>
</table>

A. $f(2) = 4$ [\(h(g(2))\)]
B. $f(2) = 0$ [\(g(x) = 2 \rightarrow h(x)\)]
C. $f(2) = 1$ [\(h(x) = 2 \rightarrow g(x)\)]
D. It is not possible to find $f(2)$ based only on the information in the table.

General: Given only the information in the following table, find $f(a_1)$ (if possible).

<table>
<thead>
<tr>
<th>$x$</th>
<th>$h(x)$</th>
<th>$g(x)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$a_1$</td>
<td>$c_1$</td>
<td>$b_2$</td>
</tr>
<tr>
<td>$b_2$</td>
<td>$b_3$</td>
<td>$c_1$</td>
</tr>
<tr>
<td>$a_2$</td>
<td>$a_3$</td>
<td>$a_1$</td>
</tr>
</tbody>
</table>

A. $f(a_1) = b_3$ [\(h(g(a_1))\)]
B. $f(a_1) = a_3$ [\(g(x) = a_1 \rightarrow h(x)\)]
C. $f(a_1) = c_1$ [\(h(x) = a_1 \rightarrow g(x)\)]
D. It is not possible to find $f(a_1)$ based only on the information in the table.
CONCEPTIONS IN EXAMPLE

General: Given only the information in the following table, find \( f(a_1) \) (if possible).

<table>
<thead>
<tr>
<th>( x )</th>
<th>( h(x) )</th>
<th>( g(x) )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( a_1 )</td>
<td>( c_1 )</td>
<td>( b_2 )</td>
</tr>
<tr>
<td>( b_2 )</td>
<td>( b_3 )</td>
<td>( c_1 )</td>
</tr>
<tr>
<td>( a_2 )</td>
<td>( a_3 )</td>
<td>( a_1 )</td>
</tr>
</tbody>
</table>

A. \( f(a_1) = b_3 \) \[ h(g(a_1))] 
B. \( f(a_1) = a_3 \) \[ g(x) = a_1 \to h(x)] 
C. \( f(a_1) = c_1 \) \[ h(x) = a_1 \to g(x)] 
D. It is not possible to find \( f(a_1) \) based only on the information in the table.

A. Does not recognize need for reversal (Action).
B. Recognizes need for reversal and order of composition (Successful Process).
C. Recognizes need for reversal but incorrect order of composition (Unsuccessful Process).
D. Views a function as a single algebraic formula (PreAction).
VICTORY!
Victory!
**Benefits**

Benefits of utilizing RUME literature and AIG:

- (Potentially) efficient assessment of student understanding.
- Using AIG, a large group of question types can yield an incredible amount of multiple-choice items.
- The groundwork (open-ended analysis of student conceptions) already exists in the RUME literature.
- Practical application of RUME knowledge.
- Potential entry-level research projects for undergraduates/early graduates.
THANK YOU!

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Application of AIG - Course
Application of AIG - Diagnostic Assessments