A multilevel analysis of the effects of external rewards on elementary students’ motivation, engagement and learning in an educational game

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Acknowledgements

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• Research Assistants: Ellen Jameson, Steven Zuiker, Adam Ingram-Goble, Eun Ju Kwon
• Teacher: Jake Summers
Participatory Assessment
Design Principles

Let contexts give meaning to conceptual tools

Reward disciplinary engagement

Grade reflections rather than artifacts

Assess individual understanding prudently

Measure aggregated achievement discreetly
Taiga Ecological Sciences Curriculum

- 13 hours of grade 4-6 curriculum:
  - Ecology (e.g., erosion and eutrophication).
  - Chemistry (e.g., dissolved oxygen).
  - Scientific and socio-scientific inquiry.
Taiga Challenge

• Assist Ranger Bartle
• Why are the fish dying?
  – Interview NPCs (non-player characters).
  – Take and analyze water quality samples.
• Balance needs of diverse users
  – Sportfishers, loggers, farmers, and visitors
  – Can’t blame one group
  – Support both scientific and socioscientific Inquiry
Example Quest

• Why fish are dying?
  – Interpret indicators (e.g., pH, turbidity)
  – Understand processes (e.g., eutrophication)
  – Coordinate data and theory
• Submit for review by teacher (as Ranger)
  – Revise and resubmit for learning

Your goal(s) are to:

In this Quest, you collected water from the river and analyzed it with Abby. Now respond to three challenges below, using the lab results as evidence.

- Summarize how the indicators in the water change from site to site. Use your own words—Ranger Bartle already has a copy of the chemical chart, but he needs you to explain what it means.
- How does this data help explain why the fish are dying?
- What's going on in Taiga that might be causing the different indicator values? Explain how the Mulu, the fishing company, and the loggers either contribute to or are victims of the fish decline problem.

Submit Your Response to This Quest

<table>
<thead>
<tr>
<th>Attachment 1 (optional)</th>
<th>Attachment 2 (optional)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attachment 3 (optional)</td>
<td>Attachment 4 (optional)</td>
</tr>
</tbody>
</table>

Describe Your Attachment(s) or Paste Your Response

turbidity, and this floats down to Station C, the fishers’ land, as well as the stuff from station A. As a result, station C has a mixture high turbidity and high levels of nitrates and phosphates. This means that the fish at station C are dying because of the fishers’ activities and from eutrophication. The Mulu contribute to this problem by farming too close to the river. If they had more land, they could farm further away from the water, and that would solve the problem of eutrophication. The fishers are victims and contributors of this problem. They contribute to the problem by damaging the fish when
## Taiga Assessment by Level

<table>
<thead>
<tr>
<th>LEVEL (Orientation)</th>
<th>ASSESSMENT</th>
<th>PRIMARY FORMATIVE FUNCTIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>CLOSE (Activity)</td>
<td>Analyze Content of Quest Submissions</td>
<td>Refine activities, advance learner understanding</td>
</tr>
<tr>
<td>PROXIMAL (Curriculum)</td>
<td>Open-ended performance assessment</td>
<td>Guide refinement of the curriculum, formal remediation</td>
</tr>
<tr>
<td>DISTAL (Standards)</td>
<td>Randomly selected test items aligned to targeted standards</td>
<td>Convince broad audience of curricular value</td>
</tr>
</tbody>
</table>
Incentives, Competition, Engagement, & Learning

• 30-year debate over extrinsic incentives
• Incentives used in most games that get played
• Current studies on motivation and gaming
  – Correlate self-________ and learning or measure gains in self-________
• Hickey & Schafer (2006, *Handbook of*) laid out a three level model
  • Close engagement
  • Proximal understanding & situational interest
  • Distal achievement and personal interest
Feedback and Learning

• Feedback is essential in learning environments
  – Supports continued engagement.
  – Don’t need to prove feedback “works.”
• Feedback on engagement in academic setting usually requires assessment.
  – Formal assessment interrupts experience.
  – Presents crucial balancing act
• Feedback must be useful *and* used:
  – Must consider timing, target, and form.
# Quest Atlantis: Taiga Quest 2 - Beyond Opinion

## Scoring and Feedback Rubric

### Overview
Use this rubric to review Quest 2 submissions and provide formative feedback. A “complete” submission will show understanding of both water quality indicators and ecological process, and how they work in synthesis. Few submissions are likely to be complete. Students whose submissions are not judged complete need to visit the lab technician who will review these concepts before students resubmit Quest 2.

### Instructions
1. Before using rubric, review the knowledge tables and example responses in the appendix.
2. Review each submission for evidence of the three types of understanding using the rubric below.
3. Assign from 0 to 3 points to each submission.
4. Accept submissions judged complete (3 points) and reject others.
5. Cut and paste the corresponding feedback into the feedback submission box.

### Table

<table>
<thead>
<tr>
<th>1. Indicators</th>
<th>2. Ecological Processes</th>
<th>3. Synthesis</th>
<th>Teacher Feedback (Copy and paste it as Reviewer Comments and Feedback)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Do they understand the various water quality indicators?</td>
<td>Do they understand erosion and eutrophication?</td>
<td>Do they understand how indicators and processes interact?</td>
<td>Hi! This is Ranger Bartle. Really great job on this Quest! Your understanding of the chemical indicators and their relation to water quality has really brought us closer to figuring out what is happening in Taiga. You are quite a field investigator. Thank you so much for your hard work and thorough analysis.</td>
</tr>
<tr>
<td>Requires accurate and detailed description of the changes in indicators along the river.</td>
<td>Requires accurate characterization both processes.</td>
<td>Requires accurate integration evidence and processes</td>
<td>Hi! This is Ranger Bartle. Thank you so much for your help on this Quest, but I cannot still understand what is causing the fish decline. I want you to revise this Quest. The Lab Technician has volunteered to help you out. Before revising, you must visit the Lab Technician, and talk with him about how you can use the indicators as scientific evidence of changes in an ecosystem. You need this to revise your Quest.</td>
</tr>
<tr>
<td>3 Complete</td>
<td>Yes</td>
<td>Yes</td>
<td>Hi! This is Ranger Bartle. Thank you so much for your help on this Quest, but I cannot still understand what is causing the fish decline. I want you to revise this Quest. The Lab Technician has volunteered to help you out. Before revising, you must visit the Lab Technician, and talk with him about what erosion and eutrophication mean and how you can use the indicators as scientific evidence of changes in an ecosystem. You need this to revise your Quest.</td>
</tr>
<tr>
<td>2 Near-Complete</td>
<td>Yes</td>
<td>Yes</td>
<td>Hi! This is Ranger Bartle. Thank you so much for your help on this Quest, but I cannot still understand what is causing the fish decline. I want you to revise this Quest. The Lab Technician has volunteered to help you out. Before revising, you must visit the Lab Technician, and talk with him about how indicators are changing along the Taiga River, what erosion and eutrophication mean and how you can use the indicators as scientific evidence of changes in an ecosystem. You need this to revise your Quest.</td>
</tr>
<tr>
<td>1 Partial</td>
<td>Yes</td>
<td></td>
<td>Hi! This is Ranger Bartle. Thank you so much for your help on this Quest, but I cannot still understand what is causing the fish decline. I want you to revise this Quest. The Lab Technician has volunteered to help you out. Before revising, you must visit the Lab Technician, and talk with him about how indicators are changing along the Taiga River, what erosion and eutrophication mean and how you can use the indicators as scientific evidence of changes in an ecosystem. You need this to revise your Quest.</td>
</tr>
<tr>
<td>0 Incomplete</td>
<td></td>
<td></td>
<td>Hi! This is Ranger Bartle. Thank you so much for your help on this Quest, but I cannot still understand what is causing the fish decline. I want you to revise this Quest. The Lab Technician has volunteered to help you out. Before revising, you must visit the Lab Technician, and talk with him about how indicators are changing along the Taiga River, what erosion and eutrophication mean and how you can use the indicators as scientific evidence of changes in an ecosystem. You need this to revise your Quest.</td>
</tr>
</tbody>
</table>
New Formative Feedback Routine

Lab Technician

"Hello! I've had some experience with water quality analysis that you might find very helpful. I'll be happy to share with you what I know. I know we've already talked about the water quality indicators you measured, like pH and turbidity. Are you sure you know what they mean, or would you like to go over them briefly?"

---

Table:

<table>
<thead>
<tr>
<th>Chemical Indicator</th>
<th>Results (A)</th>
<th>Results (B)</th>
<th>Results (C)</th>
<th>Sources and Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>6.6</td>
<td>7.0</td>
<td>7.3</td>
<td>A pH of 6.5 to 7.5 is usually very good. Less than 5.5 and greater than 8.5 is usually bad for aquatic life. (Read More)</td>
</tr>
<tr>
<td>DO</td>
<td>5.5 ppm</td>
<td>4.5 ppm</td>
<td>4.0 ppm</td>
<td>Dissolved oxygen levels between 5 and 6 parts per million (ppm) are usually needed for large fish to thrive. Levels below 3 ppm are very stressful to aquatic life. (Read More)</td>
</tr>
<tr>
<td>turbidity</td>
<td>6 NTU</td>
<td>27 NTU</td>
<td>22 NTU</td>
<td>Turbidity values of 5 NTU (turbidity units) or less are excellent for many freshwater fish. Values greater than 25 NTU are bad for most fish. (Read More)</td>
</tr>
<tr>
<td>nitrates</td>
<td>3.15 ppm</td>
<td>0.96 ppm</td>
<td>2.08 ppm</td>
<td>Nitrate values less than 0.3 ppm are excellent and nitrate values greater than 2.0 ppm are poor. (Read More)</td>
</tr>
<tr>
<td>phosphates</td>
<td>3.6 ppm</td>
<td>1.70 ppm</td>
<td>3.08 ppm</td>
<td>Phosphate values less than 0.1 ppm are excellent and phosphate values greater than 3.0 ppm are poor. (Read More)</td>
</tr>
<tr>
<td>temperature</td>
<td>17.5 C</td>
<td>22.5 C</td>
<td>22.0 C</td>
<td>If the temperature in a waterway from one location to another changes more than 5 C, aquatic life can become very stressed. (Read More)</td>
</tr>
</tbody>
</table>

Lab Technician

"Please help me to review how the indicators change along Taiga River. Let me know if I am wrong. So in site C near the K-fly Fishing Company, DO, nitrates, turbidity, phosphates are in the unhealthy range for fish. Near the Mulu village,
Learning Gains Across Implementations (in SD)

- 2006 Non-QA Custom Text Comparison (62)
- 2006 QA Tiaga Version 2 (54)
- 2007 QA w/Feedback (94)
- 2008 QA w/Feedback (50)
- 2008 QA w/Feedback + Incentive (50)

**Proximal**
- Problem Solving

**Distal**
- MC Achievement
Challenges to Studying Incentives in Immersive Contexts with DBR

• Individual game and social Game
  – Most motivation and assessment studies embrace an aggregative reconciliation
  – Assessment model embraces a dialectical reconciliation.

• Embedding quasi-experiments in DBR

• Experimental studies of consequential incentives
  – Most important incentives of all
2008 Study of Badges & Incentives

• Manipulated public recognition of questing success:
  – Public Recognition w/ badges & leaderboard
  – No Incentive w/ only “intrinsic” incentives

• Refined the formative feedback routine
  – List of 30 FAQs
# 2008 Incentive Study

## Motivation Outcomes & Measures

<table>
<thead>
<tr>
<th>LEVEL (Orientation)</th>
<th>Outcome</th>
<th>Measure</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CLOSE (Activity)</strong></td>
<td>Intentionality during Quest 2 and formative feedback</td>
<td>Appropriate use of formalisms in Quest 2</td>
</tr>
<tr>
<td><strong>PROXIMAL (Curriculum)</strong></td>
<td>Intrinsic motivation during Quest 2 task</td>
<td>Self-reported motivational state during Quest 2</td>
</tr>
<tr>
<td><strong>DISTAL (Standards)</strong></td>
<td>Motivation towards academic content in Taiga.</td>
<td>Gains in self-reported interest and value in solving ecology problems</td>
</tr>
</tbody>
</table>
## Motivational State Survey (proximal)

<table>
<thead>
<tr>
<th>Scale (# items)</th>
<th>Example Item</th>
<th>Reliability (alpha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interest (5)</td>
<td>I enjoyed doing Quest 2 very much</td>
<td>$\alpha = .896$</td>
</tr>
<tr>
<td>Value (4)</td>
<td>I think that doing Quest 2 was useful for learning about water quality (e.g. erosion, Ph, D.O.....)</td>
<td>$\alpha = .767$</td>
</tr>
<tr>
<td>Competence (4)</td>
<td>I was a pretty skilled at doing Quest 2.</td>
<td>$\alpha = .781$</td>
</tr>
<tr>
<td>Effort (5)</td>
<td>I put a lot of effort into doing Quest 2.</td>
<td>$\alpha = .802$</td>
</tr>
<tr>
<td>Name (items)</td>
<td>Stem</td>
<td>Sample Item</td>
</tr>
<tr>
<td>----------------------</td>
<td>------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Water Quality</td>
<td>How do you feel about scientific problems involving water quality and ecology (e.g. how fish, river plants and other aquatic life are impacted by development, logging, erosion, watershed damage, etc.)?&quot;</td>
<td>3. There is a chance I would take some action (e.g., send an email, collect some data, etc) to help solve water quality problems.</td>
</tr>
<tr>
<td>Complex Science</td>
<td>How do you feel about scientific problems where the solution to one problem might create other problem (e.g. disposing of nuclear waste, damming a nice river to provide water for agriculture, etc.)</td>
<td>5. I might choose to read an article in the newspaper about these kinds of problems.</td>
</tr>
<tr>
<td>Controversial Science</td>
<td>“How do you feel about controversial scientific problems that involve complex social, moral, and ethical issues (e.g., genetic engineering, stem cell research, cloning, etc.)&quot;</td>
<td>4. There are lots of other things that I would rather study than these kinds of problems.</td>
</tr>
</tbody>
</table>
CLOSE ENGAGEMENT & LEARNING
Frequency of Enlisted Formalisms

![Bar chart showing the frequency of enlistments in different domain formalisms under Public Recognition and No Incentive conditions.](chart.png)
CLOSE ENGAGEMENT & LEARNING
Frequency of Accurately Enlisted Formalisms

- Algae
- DO
- Erosion
- Nitrates
- Ph
- Phosphates
- Sediments
- Temperature
- Topography
- Turbidity

- Public Recognition (n=20)
- No Incentive (n=20)
Learning Gains Across Implementations (in SD)

- 2006 Non-QA Custom Text Comparison (62)
- 2006 QA Tiaga Version 2 (54)
- 2007 QA w/ Feedback (94)
- 2008 QA w/Feedback (50)
- 2008 QA w/Feedback + Incentive (50)

- Problem Solving (Proximal)
- MC Achievement (Distal)
PROXIMAL ENGAGEMENT
Self-Reported Motivational Experience in Quest 2

Five-Point Likert Scale

- **Interest** $(\alpha = .82)$
- **Value** $(\alpha = .81)$
- **Competence** $(\alpha = .84)$
- **Effort** $(\alpha = .78)$

**Private** $(2, 56)$
**Public** $(2, 52)$

All $F < 1$
DISTAL ENGAGEMENT
Changes in Self-Reported Interest (Ecology)

Interest in Water Ecology

<table>
<thead>
<tr>
<th>Self-Reported Interest (1-5)</th>
<th>Pre (α = .76)</th>
<th>Post (α = .79)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Private (2,53)
Public (2,51)

$F(1, 102) = .44, p = .5$
DISTAL ENGAGEMENT
Changes in Self-Reported Interest (Complex Science)

Interest in Complex Science

Self-Reported Interest (1-5)

Pre (α = .73)  Post (α = .79)

Private (2,53)  Public (2,51)

F (1,101) = .7, p = .5
DISTAL ENGAGEMENT
Changes in Self-Reported Interest (Controversial Science)

Interest in Controversial Science

Self-Reported Interest (1-5)

Pre ($\alpha = .73$)  Post ($\alpha = .79$)

$F (1, 101) = 1.03, p = .3$
Summary & Conclusions

• Slight positive impact on disciplinary engagement, cognitive engagement, & interest
• Significant positive impact on proximal understanding and distal achievement
• Supports Collins et al. (1989) and Hickey (2003)
  – Competition seems okay as long as there is feedback and opportunity to improve
  – Seems unlikely that incentives that empower students would also disempower them
• Shows value of DBR and participatory model
• Supports prevailing QA incentive practice
Summary & Conclusions in Filsecker & Hickey (2014)

- No impact on engagement or motivation
- No impact on distal achievement
- Positive impact on proximal understanding
Analysis Issues

• How to relate individual & social
  – Immediate-level analysis of engaged participation
  – Role of teachers, where to go with DBIR

• Engaged participation as motivation
  – The intrinsic/extrinsic dichotomy remains primary

• How do we study consequential incentives?
  – How can incentivizing autonomy undermine autonomy?


