Effects of Discussion Strategies and Learner Interactions on Performance in Online Mathematics Courses: An Application of Learning Analytics

Instructional Technology & Learning Sciences Department
Ji-Eun Lee
Introduction
Problem Statement & Possible Solution

Problem

• High failure rates in college math courses; higher in online math courses

What we know

• In mathematics learning contexts, a few studies found that the use of online discussions helped in
  - decreasing math anxiety
  - increasing achievement outcomes
• Learners performed better in “effectively designed and structured online discussions”

Challenges in Practice & Research

• Instructors seldom design/implement structured online discussions
• Prior studies tended to focus on students’ discussion behaviors rather than instructor involvement
• Little research in mathematics learning contexts
Question: What discussion design works best in online math courses?
Research Purposes

For online introductory mathematics courses:

01 Exploring instructors’ use of discussion strategies that enhance meaningful learner interactions and performance

02 Investigating learner behaviors and interaction patterns that lead to better performance
RESEARCH QUESTIONS

RQ1
What design strategies for online discussions are associated with positive student performance?

RQ2
How do different design strategies in online discussions impact the kinds of learner interactions?

RQ3
What types of learner interactions are associated with positive student performance?

*Adopted from Biggs’s 3P (Presage-Process-Product) model of teaching and learning
Canvas Learning Management System (LMS) used at a public university located in the western U.S.

- Fully online introductory (0 and 1000 levels) math/statistics courses offered between 2011 fall and 2015 summer
- Courses that used online discussions

**Methods**

**Research Context & Sample**

- **Courses**
  - # of courses: N = 72
  - # of instructors: N = 11

- **Students**
  - # of students: N = 2,869
  - Unique #: N = 2,404

- **Activities (Discussion topics)** (N = 703)
  - **Events/Actions (Discussion messages)**
    - Instructors: 1,284 messages
    - Students: 20,884 messages
METHODS
Workflow & Data Analysis Methods

Knowledge Discovery in Databases (KDD) Process

- Selection
- Pre-processing (Data cleaning)
- Transformation
- Data mining
- Interpretation/Evaluation

**Canvas**
- Clickstream data
- Textual data
- Registration system Data
- Text Mining

**LMS**
- SQL Server
- LightSide
- R Studio

**RQ1:** Classification and Regression Tree

**RQ2:** Kruskal-Wallis H Test

**RQ3:** Hierarchical Linear Modeling

- Instructors’ Use of Discussion Strategies
- Learner Interactions
- Course Performance
Instructor’ Use of Discussion Strategies

**Discussion design**
- Grouping
  - Whole-class
  - Small group
- Types of setting
  - Threaded
  - Side-comments
- Types of Discussion prompts
  - Open-ended
  - Other
- Monitoring
  - Instructor participation
- Monitoring & Facilitation
- Types of Feedback
  - Instructional
  - Conversational
  - Operational
- Use of grades
  - Graded
  - Not-graded
  - Partially graded

**Constructs**

**Variables**

**Data sources**

- Log Data
- Textual Data
METHODS
Data Pre-processing (Text mining)

1. Hand-coded 10% of messages
   • IRR: .908 ($p = .00$)
2. Imported the training into LightSIDE
   • Unigrams + Bigrams + Trigrams
3. Four built-in algorithms
   : Naïve Bayes classifier, Logistic regression, Support Vector Machines (SVM), Decision trees
4. 10-fold cross-validation
   • Confusion matrix
   • Accuracy, Kappa values
5. Hand-coded 50% of messages
6. Applied the developed model to the rest of the dataset (50% of the discussion messages)
PRELIMINARY RESULTS
Semi-automated Content Analysis

Initial Prediction Models
(hand-coding: 10% of discussion messages)

<table>
<thead>
<tr>
<th>Model</th>
<th>Prediction accuracy</th>
<th>Cohen's kappa (κ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Naïve Bayes</td>
<td>0.58</td>
<td>0.29</td>
</tr>
<tr>
<td>Logistic regression</td>
<td>0.63</td>
<td>0.33</td>
</tr>
<tr>
<td>SVM</td>
<td>0.61</td>
<td>0.37</td>
</tr>
<tr>
<td>Decision Trees</td>
<td>0.48</td>
<td>0.16</td>
</tr>
</tbody>
</table>

Final Prediction Models
(hand-coding: 50% of discussion messages)

<table>
<thead>
<tr>
<th>Model</th>
<th>Prediction accuracy</th>
<th>Cohen's kappa (κ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Naïve Bayes</td>
<td>0.66</td>
<td>0.49</td>
</tr>
<tr>
<td>Logistic regression</td>
<td>0.75</td>
<td>0.60</td>
</tr>
<tr>
<td>SVM</td>
<td>0.73</td>
<td>0.57</td>
</tr>
<tr>
<td>Decision Trees</td>
<td>0.56</td>
<td>0.30</td>
</tr>
</tbody>
</table>
**PRELIMINARY RESULTS**

*Correlation analysis*

- "Instructors’ posts" showed the strongest positive correlation with the students’ average final grades ($r = .72$, $p < .05$).

- The ratio of "open-ended prompts" ($r = .69$, $p < .05$) and the ratio of "elaborated feedback" ($r = .57$, $p < .05$) showed the significant and positive correlations with the average final grades.

- The ratio of "other prompts" ($r = -.69$, $p < .05$) and the ratio of "operational feedback" ($r = -.58$, $p < .05$) showed the significant and negative correlations with the average final grades.

*Included continuous variables only*
PRELIMINARY RESULTS
RQ1: Classification and Regression Tree (CART)

*N = Number of Courses

**N = 72 (100%)
Avg. final grade = 2.02

- **Open-ended prompts < 69.0%**
  - Threaded discussions only
    - **n = 41 (56.9%)
      Avg. final grade = 1.55**
    - Elaborated Feedback < 16.8%
    - Elaborated Feedback ≥ 16.8%

- **Open-ended prompts ≥ 69.0%**
  - **n = 31 (43.1%)
    Avg. final grade = 2.64**
  - Side Comments, or Mixed settings
  - Grading = No or Partially
  - Grading = Yes

**Node 1**
- **n = 18 (25.0%)
  Avg. final grade = 1.40**

**Node 2**
- **n = 7 (9.7%)
  Avg. final grade = 1.68**

**Node 3**
- **n = 16 (22.2%)
  Avg. final grade = 1.66**

**Node 4**
- **n = 13 (18.1%)
  Avg. final grade = 2.28**

**Node 5**
- **n = 18 (25.0%)
  Avg. final grade = 2.89**
Lessons Learned & Future Work

- **Text mining (semi-automated analysis)**
  - Importance of the amount of hand-coding
  - Logistic regression outperformed other algorithms
  - Use of unigram, bigrams, trigrams altogether

- Use of open-ended discussion prompts and grading students’ messages will lead to better student performance in online mathematics courses.

Future Work

- Validation of the CART analysis results
- RQ2: Statistical Analyses (Kruskal-Wallis H Test)
- RQ3: Hierarchical Linear Modeling (HLM)
  - Interpretation and evaluation of the results
Thank you

Ji-Eun Lee | Ph.D. Candidate
Department of Instructional Technology & Learning Sciences
jieun.lee@aggiemail.usu.edu