How Collaborative Successes and Failures Become Productive: An Exploration of Emerging Understanding and Misunderstanding Turning Points in Model-Based Learning with Productive Failure

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Abstract: While computer modeling, productive failure, and contrasting cases have all been shown to support deep learning, the micro-level mechanisms supporting collaborative success in these processes remain relatively unknown. This paper reports on a detailed exploration of turning points in emerging understanding and misunderstanding in two dyads working through model-based learning activities in a productive failure learning design.

Keywords: conceptual change, collaborative learning, science education, turning points

Introduction
Computer models (Nersessian, 2008), productive failure (Kapur & Bielaczyc, 2012), and contrasting cases (Gentner, Loewenstein, & Thompson, 2003) have all been shown to support deep learning and transfer. From a sociocultural perspective, knowledge is co-constructed through interactions (Säljö, 1991). As few studies have addressed how emerging knowledge relates to interaction over time (Damşa, 2014), the collaborative mechanisms underlying how these processes work, particularly when all are combined, remains relatively unknown. In an initial exploration of these micro-level interactional mechanisms (Portolese, Markauskaite, Lai, & Jacobson, 2015), one of our findings was that segments of misunderstanding seemed to propel extended correct understanding. However, it remained to be explored what exactly occurred at these critical turning points. This paper reports on a detailed exploration of these turning points in two dyads. This initial exploration is an innovative suggestion for how a multi-layered, temporally-sensitive analysis can be applied to understand the mechanisms of emerging understanding and misunderstanding in computer-supported collaborative learning environments. It also aims to provide a foundation for further analyses and theory development.

Method
Two dyads were selected from a larger design-based research study that investigates how students learn complex climate systems knowledge with agent-based modeling tools in a productive failure context; the selected dyads improved substantially on target complexity concepts (Kelly, Jacobson, Markauskaite, & Southavilay, 2012; Portolese et al., 2015, Jacobson & Markauskaite, 2015). Four Year Nine classes at a selective Australian girls school collaborated on inquiry activities with either one or two (contrasting cases group) NetLogo (Wilensky, 1999) models. Process data included video captures of students’ faces and computer screens, transcript of students’ discussion, and written responses to activities. The interactive process data was analysed at three increasingly large parallel grain sizes – Idea, Understanding, and Experiment – using a scheme based on impact coding (Kapur, Voiklis, & Kinzer, 2008; see Portolese et al., 2015). In this approach, each segment is categorised as +1 (towards solution), 0 (not changing progress), or -1 (away from solution).

Our multi-layered parallel impact coding gave a rich picture of understanding changes during students’ problem-solving interaction. At the Understanding Level, turning points were defined as when the impact direction changed and continued for at least two segments when tackling a conceptual issue (e.g. -1, +1, +1). Across the two dyads, 26 turning points were identified (17 positive towards understanding, 9 negative towards misunderstanding). For each turning point, the Idea Level segments were analysed: a) in the Understanding Level segments before the understanding changed, and b) in the subsequent Understanding Level segments during the change itself, until two Understanding Level segments in the new direction occurred (see Table 1).

Findings and implications
Three key patterns will be discussed. First, incorrect observations were common, both before positive turning points and as the substance of negative turning points. Students grounded their knowledge construction
in their observations; when these were incorrect, misunderstandings emerged. Follow up correct observations usually reversed this pattern. Second, missing the bigger picture was an elusive problem. Similar to incorrect observations, the nature of this issue means students may not realise a problem exists. Additional observation, experimentation, and elaborated discussion supported students in approaching realisation of the bigger picture. A third pattern, poor experimental design, was simpler to turn around, as this resulted in confusion more overtly. Understanding turned largely through predictions that focused, and hence improved, experimental designs.

This initial yet deep analysis unveils some of the collaborative mechanisms that may support changes in emerging understanding and misunderstanding. The results suggest that positive turning points most often appeared with additional experimentation and observation. For practice, students should be encouraged to generate as many diverse ideas as possible (Kapur & Bielaczyc, 2012), and in particular, make predictions and careful observations before developing extended understandings. Perhaps technical or representational errors can be prevented, as these misunderstandings appear less productive. More research is needed to unpack these issues, which is the focus of our current research program.

Table 1: Selected turning point patterns

<table>
<thead>
<tr>
<th>Before Turning Point</th>
<th>Turning points</th>
<th>Key Idea Level characteristics during turn</th>
<th>How understanding turned &amp; emerged</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incorrect observations</td>
<td>4</td>
<td>Correct observations and suggestions</td>
<td>New observations</td>
</tr>
<tr>
<td>Poor experimental design</td>
<td>4</td>
<td>Correct predictions and experimental design</td>
<td>Predictions and experimentation</td>
</tr>
<tr>
<td>Missing bigger picture</td>
<td>5</td>
<td>Correct observations, explanations, understanding, and experimental design</td>
<td>Experimentation and elaborated discussion</td>
</tr>
<tr>
<td>Correct explanation; Solved technical problem; Challenged incorrect idea</td>
<td>3</td>
<td>Incorrect observations</td>
<td>Incorrect observations</td>
</tr>
<tr>
<td>Correct task orientation; Focused experiment; Partially correct understanding</td>
<td>3</td>
<td>Incorrect/correct observations, incorrect explanations, and misunderstanding</td>
<td>Focusing on wrong details (Missed bigger picture)</td>
</tr>
</tbody>
</table>

References


Gentner, D., Loewenstein, J., & Thompson, L. (2003). Learning and transfer: A general role for analogical encoding. Journal of Educational Psychology, 95, 393-408.


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