Affect Matters: Exploring the Impact of Feedback during Mathematical Tasks in an Exploratory Environment

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Abstract. We describe a Wizard-of-Oz study that investigates the impact of different types of feedback on students' affective states. Our results indicate the importance of matching carefully the affective state with appropriate feedback in order to help students transition into more positive states. For example when students were confused affect boosts and specific instruction seem to be effective in helping students to be in flow again. We discuss this and other effective ways to and implications for the development of our system and the field in general.

1 Introduction

It is well understood that affect interacts with and influences the learning process [1, 2]. While positive affective states such as surprise, satisfaction or curiosity contribute towards constructive learning, negative ones including frustration challenge learning. The learning process is indeed full of transitions between positive and negative affective states and regulating those is important.

In related work, students' affective states have been used to tailor motivational feedback and learning material in order to enhance the learning experience. For example, Santos et al. [3] show that affect as well as motivation and self-efficacy impact the effectiveness of motivational feedback and recommendations. Additionally, Woolf et al. [4] developed an affective pedagogical agent which is able to mirror a student's affective state. Another example is Conati & MacLaren [5], who developed a pedagogical agent to provide support according to the affective state of the student and their personal goal. Also, Shen et al. [6] recommend learning material to the student based on their affective state. D'Mello et al. [7] developed a system that is able to respond to students via a conversation that takes into account the affective state of the student.

In this paper, we investigate the impact of different types of feedback on students' affective state and how and whether they can help students regulate their affect and thus improve learning.

2 The Wizard-of-Oz study

One of our research aims is to develop intelligent support that enhances the learning experience by taking into account the student's affective state. We were interested in identifying how different feedback types modify affective states. We focus on a subset of affective states identified by Pekrun [8]: flow/enjoyment, surprise, frustration, and boredom. We also add confusion, which has been identified elsewhere as an important affective state during learning [9].

In total, 26 Year-5 (9 to 10-year old) students took part in a Wizard-of-Oz study where students undertook tasks in an exploratory learning environment for fractions (Fractions Lab). Each session lasted on average 20 minutes. More information about the set up of the study can be found in Mavrikis et al. [10].

Wizards followed a script with pre-specified messages to send feedback to the students through the learning platform and deliberately limited their communication capacity in order to simulate the actual system.The different types of feedback that were provided from the wizards to the students as follows:

- AFFECT - affect boosts ('You're working really hard! Well done!")
- INSTRUCTION - instructive task-dependent feedback ('Use the comparison box to compare your fractions')
- OTHER PROBLEM SOLVING - task-dependent feedback ('To add two fractions together, they first need to have the same denominator')
- TALK ALOUD - talking aloud ('Remember to talk aloud, what are you thinking?')
- REFLECTION - reflecting on task performance and learning ('Why did you change the denominator?')
- TALK MATHEMATICS - using particular domain specific mathematics vocabulary ('Can you explain that again using the terms denominator or numerator?')
- TASK SEQUENCE - moving to the next taskt ('Well Done. When you are ready, click 'next' for the next task')

We explored these particular types of feedback because the literature suggests they support students in their learning and because they fit our context [10].

From the Wizard-of-Oz study we recorded the students' screen display and their voices. From this data, we annotated affective states (e.g. screen interaction and what the students said) before and after feedback was provided.

3 Results

In total 396 messages were sent to 26 students. The video data in combination with the sound files were analysed independently by three researchers who categorised the affective states of students before and after the feedback messages were provided. Additionally, we used the Baker-Rodrigo Observation Method Protocol (BROMP) and the HART mobile app that facilitates coding of affective states in the classroom [11]. Kappa between the researchers' annotations and the HART data was .71, $p<.05$.

The affective states that occurred *before* the feedback was provided were confusion in 181 cases, flow in 169 cases, frustration in 34 cases, boredom in 9 cases, and surprise in 3 cases. The affective states that occurred *after* the feedback was sent were flow in 250 cases, confusion in 131 cases, frustration in 10 cases, boredom in 3 cases, and surprise in 2 cases.

In order to investigate whether there was an effect of the feedback on the learning experience, we looked at whether a student's affective state was enhanced (e.g. changed from frustration to confusion or flow) or was worsened (e.g. changed from flow to frustration or confusion). As the data is categorical [12], we apply chi-square tests to investigate statistical significant differences.

When students were in **flow**, there was no significant difference between the feedback types on whether the affective state stayed in the same flow state (X^2(6, N=169) = 4.31, p>.05) or worsened (X^2(6, N=169) = 4.89, p>.05).

When students were **confused**, there was a significant effect of the feedback type on whether students' affective state was enhanced into a flow state (X^2(6, N=181) = 13.65, p<.05). The most effective feedback types were affect boosts with 68% of the cases, followed by guidance feedback with 67%, and task sequence prompts with 63%. Reflective prompts resulted in a flow state in 48% of the cases, talk aloud prompts 38%, and problem solving support with 34%. Talk math prompts were the least effective with only 25% of the cases. There was no significant association between the feedback type and whether the affective state worsened (X^2(6, N=181) = 4.65, p>.05).

There was not sufficient data available when students were **frustrated**, nor when they were **bored**, or **surprised** to run a statistical test across the different affective states and feedback types.

4 Discussion and Conclusion

Our results confirm related research on the role of feedback in enhancing students' affective states, and allow us to tease apart the impact of the various feedback types on the students' affective state.

When students were in flow there was no significant difference between the feedback types on whether or not the affective state stayed the same or worsened. This suggests that, when students are in flow, challenging feedback can be provided without negative implications.

However, when students were confused there was a difference between the feedback types on whether the affective state was enhanced, stayed the same or worsened. The feedback types that most effectively moved the student out of a confusion state were affect boosts, instruction, and task sequence. When they were struggling to overcome problems, affect boosts appeared to encourage some students to redouble their efforts without the need for task specific support. We can hypothesise that this enabled students to self-regulate their affect and move forward. As expected, instructive feedback appears to have given the students the next steps that they needed, whereas other problem solving was less successful. Other problem solving feedback seems to have led students to be more confused because of the increased cognitive load to understand the hint or the question provided. While talk aloud and talk math, encouraged students to vocalize what they are trying to achieve, they appear not to have helped the students address their confusions. Instead, when they were confused, students appeared to have welcomed a new task.

Our next steps using the data collected is to train an intelligent system that is able to tailor the type of feedback according to the affective state of the student in order to enhance the learning experience and investigate in more detail the impact of feedback and affect in students' learning.

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