The impact of feedback on students' affective states

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Abstract. Affective states play a significant role in students' learning behaviour. Positive affective states can enhance learning, while negative affective states can inhibit it. This paper describes a Wizard-of-Oz study that investigates the impact of different types of feedback on students' affective states. Our results indicate the importance of providing feedback matched carefully to the affective state of the students in order to help them transition into more positive states. For example when students were confused affect boosts and specific instructive feedback seem to be effective in helping students to be in flow again. We discuss this and other ways to adapt the feedback, together with implications for the development of our system and the field in general.

1 Introduction

This paper reports the results of a set of two Wizard-of-Oz studies which explore the effect of different feedback types on students' affective states.

It is well understood by now that affect interacts with and influences the learning process [9, 6, 2]. While positive affective states such as surprise, satisfaction or curiosity contribute towards constructive learning, negative ones including frustration or disillusionment at realising misconceptions can lead to challenges in learning. The learning process is indeed full of transitions between positive and negative affective states and regulating those is important. For example, a student may seem interested in exploring a particular learning goal, however s/he might have some misconceptions and need to reconsider her/his knowledge. This can evoke frustration and/or disappointment. However, this negative affective state may turn into deep engagement with the task again. D'Mello et al., for example, elaborate on how confusion is likely to promote learning under appropriate conditions [6].

It is important therefore, to deepen our understanding of the role of affective states for learning, and to be able to move students out of states that inhibit learning. Pekrun [13] discusses achievement emotions or affective states, which arise in a learning situation. Achievement emotions are states that are linked to learning, instruction, and achievement. We focus on a subset of affective states identified by Pekrun: flow/enjoyment, surprise, frustration, and boredom. We also add confusion, which has been identified elsewhere as an important affective state during learning [15] for tutor support and for learning in general [6].

As described in Woolf et al. [20] students can become overwhelmed (very confused or frustrated) during learning, which may increase cognitive load [19] for low-ability or novice students. However, appropriate feedback might help to overcome such problems. Carenini et al. [3] describe how effective support or feedback needs to answer three main questions: (i) when the support should be provided during learning; (ii) what the support should contain; and (iii) how it should be presented.

In this paper we focus on the question of *what* the support should contain with respect to affect i.e. the types of feedback that are able to induce a positive affective state.

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. [17] show that affect as well as motivation and self-efficacy impact the effectiveness of motivational feedback and recommendations. Additionally, Woolf et al. [20] developed an affective pedagogical agent which is able to mirror a student's affective state, or acknowledge a student's affective state if it is negative. Another example is Conati & MacLaren [5], who developed a pedagogical agent to provide support according to the affective state of the students and the user's personal goal. Also, Shen et al. [18] 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 contrast, 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. In what follows we present two sets of Wizard-of-Oz studies where feedback was provided to students interacting with an exploratory learning environment designed to learn fractions. From these studies, the affective states of the students were carefully annotated in order to address our research questions.

2 The Wizard-of-Oz studies

2.1 Aims

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 specifically interested in identifying how different feedback types modify affective states.

In order to address this question we conducted two sets of ecologically valid Wizard-of-Oz studies (e.g. [11, 8]) which investigated the effect of affective states on different feedback types at different stages of the task.

2.2 Participants and Procedure

In total, 26 Year-5 (9 to 10-year old) students took part in the Wizard-of-Oz studies. Each session lasted on average 20 minutes. Each student participated in one Wizard-of-Oz session.

The sessions were run in an ordinary classroom with multiple computers, where additional children were working with the learning platform (not wizarded) in order to support ecological validity. This was important particularly as in early settings we identified that children would not speak that much to the platform if they felt that they were monitored [10]. Figure 1 shows the setup of the studies. Wizards followed a script with pre-canned messages to send messages to the students through the learning platform and deliberately limited their communication capacity in order to simulate the actual system. To achieve that wizards were only able to see students' screen. An assistant was able to hear students' reactions to reflections or talk-aloud prompts (as prompted by the 'system') and provide recommendations to the wizard with respect to the detected affective state. Any feedback provided was both shown on screen and read aloud by the system to students.

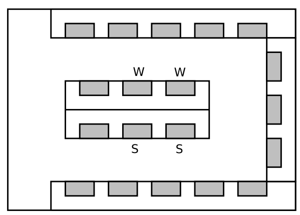

Fig. 1. The layout. The Wizard-of-Oz studies took place on the central isle while the rest of the students worked on a version of the system which only sequences tasks and provides minimal support (W=wizard, S=student).

2.3 Feedback types

Different types of feedback were presented to students at different stages of their learning task. The feedback provided was based on interaction via keyboard and mouse, as well as speech.

We explore different types of feedback that are known from the literature to support students in their learning and fit our context. The following different feedback types were provided:

– **AFFECT BOOSTS - affect boosts**. As described in [20] affect boosts can help to enhance student's motivation in solving a particular learning task. These included prompts that acknowledged for example that a task is difficult or that the student may be confused but they should keep trying.

- **INSTRUCTIVE FEEDBACK - instructive task-dependent feedback**. This feedback provided detailed instructions, what subtask or action to perform in order to solve the task.
- **OTHER PROBLEM SOLVING FEEDBACK - task-dependent feedback**. This support was centred on helping students to solve a particular problem that they are facing during their interaction by providing either questions to challenge their thinking or specific hints designed to help them identify the next step themselves.
- **TALK ALOUD PROMPTS - talking aloud**. With respect to learning in particular, the hypothesis that automatic speech recognition (ASR) can facilitate learning is based mostly on educational research that has shown benefits of verbalization for learning (e.g., [1]).
- **REFLECTIVE PROMPTS - reflecting on task performance and learning**. Self-explanation can be viewed as a tool to address students' own misunderstandings [4] and as a 'window' into students' thinking.
- **TALK MATHEMATICS PROMPTS - using particular domain specific mathematics vocabulary**. The aim of this prompt was to encourage students to use mathematical vocabulary in order continually revise their interpretations. In early studies [10] we found that students' reflections were often procedural and pragmatic (e.g. talking about the user interface) rather than mathematical.
- **TASK SEQUENCE PROMPTS - moving to the next task**. This feedback is centred on providing support regarding what action to perform next in order to change the task, such as clicking the 'Next' button.

Table 1 shows examples of the different feedback types.

3 Annotation of affective states and feedback reactions

From the Wizard-of-Oz studies 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.

As described earlier, for the affective state detection we discriminated between five different affective types: enjoyment, surprise, confusion, frustration, and boredom. For the annotation of those affective states we used a similar strategy to that described in [15], where a dialogue between a teacher and a student was annotated retrospectively by categorising utterances in terms of different feedback types. Also, [2] describe how they coded different affective states based on observations of students interacting with a learning environment. Similarly, we annotated student's affective states for each type of feedback provided. In addition to the student's voice we also used the video of the screen capture to support the annotation process. Students' affective states were annotated as follows:

- **FLOW:** Engagement with the learning task. Statements like 'I am enjoying this task' or 'This is fun'. Sustained interaction with the system.

Feedback type	Example
AFFECT BOOSTS	You're working really hard! Keep going!
INSTRUCTIVE FEEDBACK	Use the comparison box to compare your fractions.
OTHER PROBLEM SOLVING FEEDBACK	If you add fractions, they need to have the same denominators first.
REFLECTIVE PROMPTS	What do you notice about the two fractions?
TALK ALOUD PROMPTS	Remember to talk aloud, what are you thinking?
TALK MATHEMATICS PROMPTS	Can you explain that again using the terms denominator, numerator?
TASK SEQUENCE PROMPTS	Well done. When you are ready click 'next' for the next task.

Table 1. Examples of feedback types

- **SURPRISE:** Gasping. Statements like 'Huh?' or 'Oh, no!'.
- **CONFUSION:** Failing to perform a particular task. Statements such as 'I'm confused!' or 'Why didn't it work?'. Uncertain interaction with the system.
- **FRUSTRATION:** Tendency to give up, repeatedly clicking or deleting of objects in the system or repeatedly failing to perform a particular task, sighing, statements such as, 'What's going on?!'.
- **BOREDOM:** Inactivity or statements such as 'Can we do something else?' or 'This is boring'.

4 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 (one was independent of the project) who categorised the affective states of students before and after the feedback messages were provided.

The data is combined from two sets of Wizard-of-Oz studies. We use kappa statistics to measure the degree of the agreements of the annotations for reliability. Kappa was .46, $p<.001$. This is generally expected from retrospective annotation of naturalistic affect experiences [14]. We consolidated the annotations based on discussion between the annotators and the rest of the authors of the paper in order to agree upon the annotations that did not match originally. In the second set we had resources to introduce the Baker-Rodrigo Observation Method Protocol (BROMP) and the HART mobile app that facilitates the coding of students affective states in the classroom [12]. Kappa based on the retrospective annotation was still .56, $p<.001$. We first consolidated the data with the same approach as before and then compared against the field annotations. Kappa between the consolidated annotation and the HART data was .71, p<.05 (note that is may appear low but we did not expect the retrospective annotation to get surprise and frustration accurately). We used the HART data to improve the annotation by mapping feedback actions against the observation for 20 seconds prior to the delivery of the feedback to 20 seconds after the student had closed the corresponding feedback window. We marked the changes for an independent annotator to revisit the first set of annotations.

The student's affective states, that occurred before and after the different types of feedback was provided, can be seen in figure 2. Each block shows an affective state *before* feedback was provided. The colour within the bars indicates the type of affective states that occurred *after* the feedback was provided. The number within the bars indicate the number of times the affective state occurred.

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, stayed the same or worsened. An affective state was enhanced for example, when it was changed from confusion to flow, or (given the findings about confusion [6]) from frustration to confusion, frustration to flow, boredom to flow etc. An affective state was worsened if it moved for example, from flow to frustration or confusion, or from confusion to frustration.

As the data is categorical [16], we apply chi-square tests to investigate statistical significant differences between the groups. We present them below and discuss in more detail in the next section.

Flow 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). As flow is the most positive affective state, the affective state in this sub-sample cannot be enhanced.

Confusion 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 maths prompts were the least effective with only 25% of the cases.

There was also a significant effect of the feedback type and whether the affective state stayed the same (X^2(6, N=181) = 14.34, p<.05). Talk maths prompts were highest associated with a continuing confused state with 75% of the cases. This was followed by problem solving support with 66%, talk aloud prompts with 59%, reflective prompts with 52%, task sequence prompts with 37%, affect boosts with 32%, and the least feedback type that was associated with a continuing confused state were guidance feedback with 29% 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).

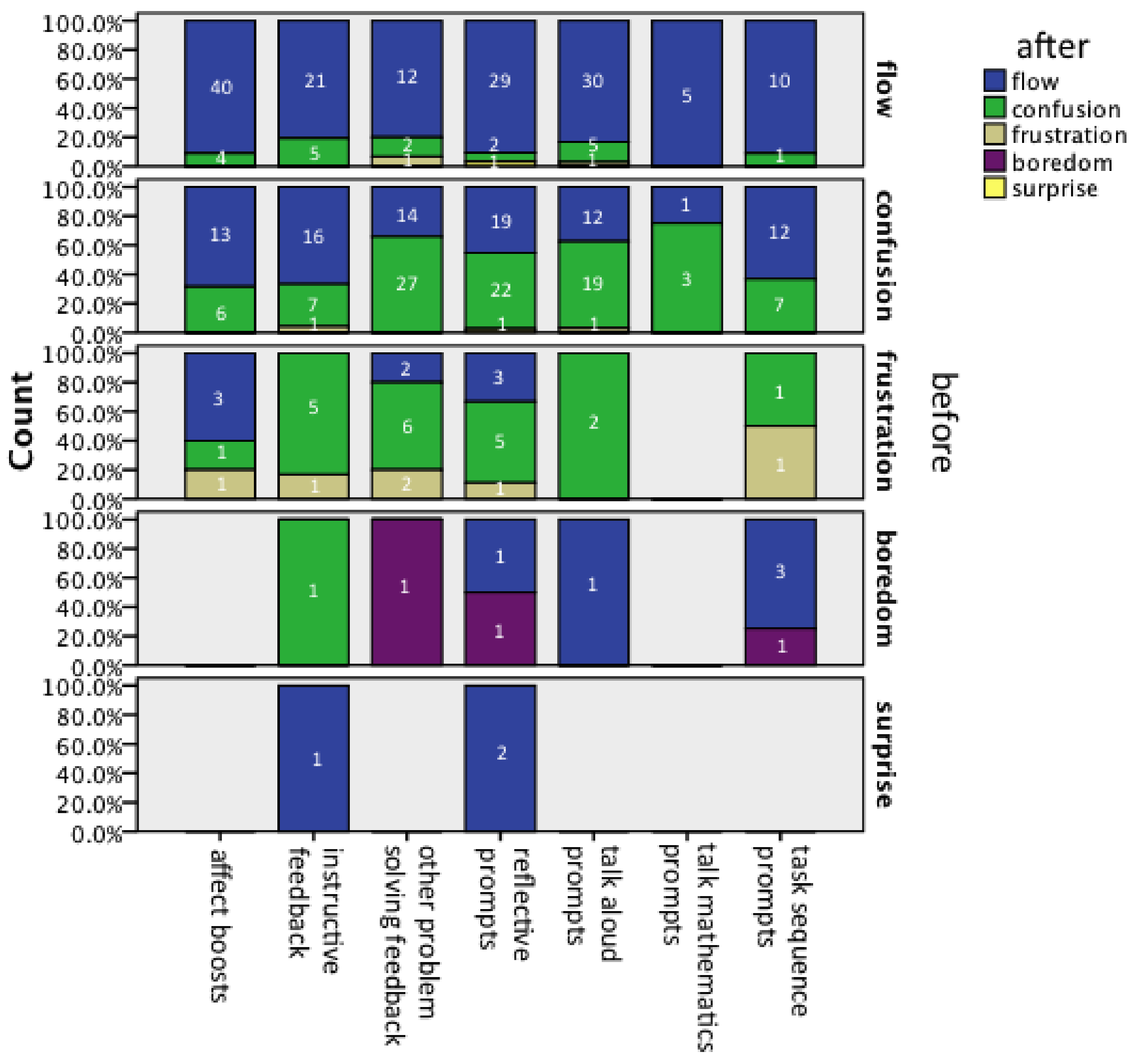

Fig. 2. Students' affective states before and after feedback was provided. Each block shows an affective state *before* feedback was provided. The colour within the bars indicates the type of affective states that occurred *after* the feedback was provided. The number within the bars indicate the number of times the affective state occurred.

Frustration, boredom and surprise There was not sufficient data available when students were frustrated (36 cases), nor when they were bored (9 cases), or surprised (3 cases) to run a statistical test across the different affective states and feedback types.

However, the data indicates that some of the provided feedback types were better able to change the affective state of the student when they were frustrated, bored or surprised, as can be seen in figure 2. For example, 60% of the affect boosts were able to change frustration into flow, followed by reflective prompts 33% and problem solving support 20%.

5 Discussion

The results presented in the previous section show that feedback can enhance students' affective states, and that the impact of the various feedback types mostly depends on the students' affective state before the feedback was provided.

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, instructive, and task sequence prompts. 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 caused by them having to understand the hint or the question provided.

While talk aloud prompts and talk maths, encouraged them 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 (the opportunity to abandon the cause of their confusion). While as a strategy this can be pedagogically debatable, there is scope to provide tasks aimed to help them at the same concepts in a different, simpler way or to allow them to practice first some skills in a practice-based rather than exploratory task.

Although there was insufficient data to analyse the impact of the different feedback types on students' affective state when they were frustrated, some tentative observations can be made. For example, it was evident that the affect of students who were frustrated was enhanced whatever the feedback they were provided with. However, it is notable that the frustrated students who were provided affect boosts were most likely to move to a flow. We have other anecdotal evidence in the same scenario with different students that suggest that explicitly addressing affect and helping students to think of their emotions during learning can help them move to confused or to flow state without need for immediate problem solving support.

It is worth noting that compared to other research we may have been unable to detect more negative states, especially boredom, because of the nature of the environment that the students were using – an exploratory learning environment that encouraged them to speak. The combination of unstructured learning and speech might prevent students from becoming bored.

6 Conclusion and future work

The affective state of students can be modified with feedback. There is a difference in the impact of different feedback types according to the affective state the student is in before the feedback was provided. Although there seems not to be too much of a difference when students are in flow, when students were confused different feedback types seem to matter more. While, for example, affect boosts and instructive feedback were able to change confusion into flow, prompting students to use mathematical vocabulary or providing other problem solving support, were associated with the same confused state or even lead to frustration.

In the light of findings like D'Mello et al. [6] for example of the importance of confusion under appropriate conditions in learning, our findings have important implications for learning and teaching in general, and AIED in particular. Problem solving support specifically in exploratory learning environments is difficult to achieve successfully, particularly when students are in a situation that was not previously encountered during a system's design. However, detecting affect may be relatively easier in certain contexts particularly in speech-enabled software like in our case and therefore affective support matters as much, if not more than, problem solving support. In addition, the exact type of support provided when students are frustrated is important. To understand this better we need to investigate more the different types of problem solving support and their combination with affective feedback that can act both as a way to self-regulate affect and take student into a more positive state like confusion or flow.

In our current study we are implying that learning performance is enhanced when students are in a positive affective state. In the future we are planning to evaluate if learning performance will be enhanced when students are moved out of a negative into a positive affective state. Our next step 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.

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