Exploring Students' Affective States During Learning With External Representations

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Abstract. We conducted a user study that explored the relationship between students' usage of multiple external representations and their affective states during fractions learning. We use the affective states of the student as a proxy indicator for the ease of reasoning with the representation. Extending existing literature that highlights the advantages of learning with multiple external representations, our results indicate that low-performing students have difficulties in reasoning with representations that do not fully accommodate the fraction as a part-whole concept. In contrast, high-performing students were at ease with a range of representations, including the ones that vaguely involved the fraction as part-whole concept.

1 Introduction

The aim of our research is to gain insights into students' learning processes in order to inform the design of technology that is able to assist students during learning and enhances their learning experience and performance. We are particularly interested in the impact of students' affective states during learning fractions with multiple external representations.

External representations (such as diagrams) are powerful aids to reasoning and problem solving (e.g. [2, 8]). Suthers [9] outlines how the choice of an external representation can influence an individual's conception of a problem, how it triggers an internal mental representation, and hence the ease of finding a solution to the problem. More specifically, in the domain of fractions, many studies show that learning with multiple external representations supports students' conceptual knowledge [7].

It is well understood that during learning students are experiencing a range of affective states [3]. While positive affective states (such as surprise, satisfaction or curiosity) contribute towards learning, negative ones (including frustration or disillusionment at realising misconceptions) can undermine learning. Any learning experience is typically full of transitions between positive and negative affective states.

In this paper, we explore students' affective states while they are performing fractions tasks with different types of external representations.

2 User study

We conducted a user study that included the iTalk2Learn platform with the exploratory learning environment *Fractions Lab*.

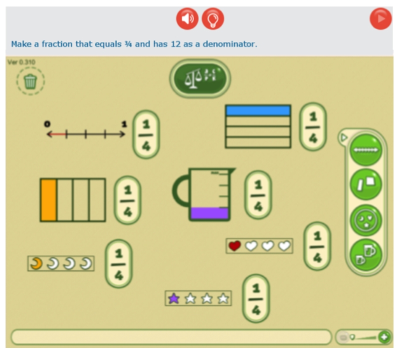

Fig. 1. Exploratory learning environment. **Fractions Lab**.

Figure 1 shows the *Fractions Lab* interface of the exploratory learning environment. The learning task is displayed at the top of the screen. Students are asked to solve the task by selecting a representation (from the right-hand side menu). The students are able to choose between the following external representations to answer the fractions task: rectangle, set, number-line, and liquid.

The external representations differed in the way how they be express a part-whole fraction concept. For example, the part-whole concept of fractions is explicitly included within the rectangle representation, as the area in itself represents one and the colour within the area represents a part of the whole fraction, which is similar to the number-line, where the numbers explicitly say that the number-line starts with zero and ends with one. In contrast, the elements within sets can be seen as discrete entities instead of being a part of the whole group of sets within the fraction. This is similar to the liquid representation as there is no clear separator of the liquid for the value of the numerator. Only the scale on the right hand side of the liquid gives and indication about the actual value of the numerator.

While students are interacting with the learning environment they are asked to talk aloud about their reasoning process. This is used to detect and analyse student's speech in near real time (c.f. [6]). The analysis of the speech and students' interaction with the exploratory learning environment are used to detect their affective states. Adaptive support is provided based on students' affective states [4].

In this user study reported here, we are interested in exploring how students' affective state and their interactions with the different external representations relate to each other. 41 participants took part in the study. They were all primary school students, aged between 8 and 10 years old. Students engaged with fractions tasks in the iTalk2Learn platform for 40 minutes. During this time all the interactions with the external representations in *Fractions Lab*, as well as the students' affective states, were stored in a database. After the 40 minutes, students completed an online questionnaire that assessed their knowledge of fractions (a post-test).

3 Results

Students' performance based on the post-test score was on average 3.83 (SD=1.46; min=0; max=6). A medium split of students' post-test score resulted in a high- and low-performance group (high: 27 students; low: 14 students).

In order to investigate the relationship between students' affective state and their representational usage we used association rule learning (e.g. [1]) over the data set that was gathered while students were using *Fractions Lab* .

Only very few students were detected as being *bored* or *frustrated* (bored: 1.3%; frustrated: 4.9% of all cases) and there was no automatic detection of *surprise*. To further analyse our data we combined the affective states of boredom and frustration into a new variable called 'negative' as those were negative affective states. The resulting graphs of the association rule learning for low- and high-performing students can be seen in Figure 2. It is a graph-based visualisa-

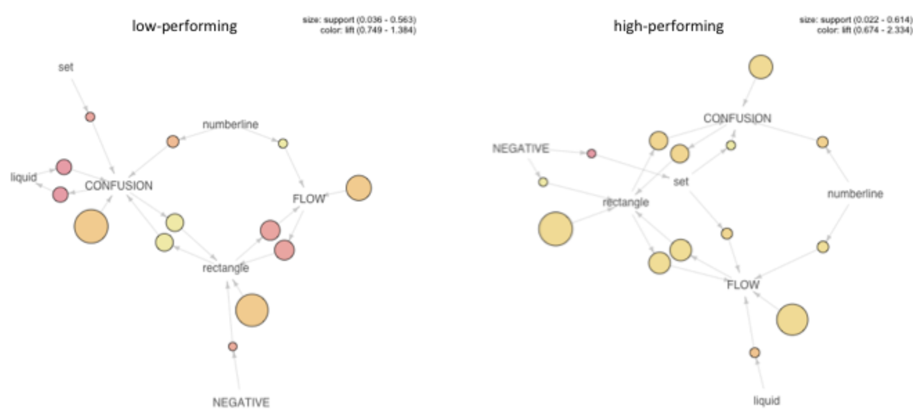

Fig. 2. Association rule graph for low- and high-performing students.

tion with variables and rules as vertices, which are connected by directed edges [5].

Figure 2 shows that for low-performing students some representations were only associated with one affective state, like liquids or sets who are associated with *confusion*. However, other representations, such as rectangles and number-lines were associated with several affective states, like being *in flow* and *confusion*. In contrast, for high-performing students the liquid representation is associated with being *in flow*. Rectangles, number-lines and sets were mainly associated with being *in flow* and *confusion* in the high-performing group.

Overall, the association rule graphs show that high-performing students were in flow with a wider range of representations than the low-performing group, including the representations that only vaguely include the part-whole fraction concept (sets and liquids).

4 Discussion and Conclusion

Our results indicate that low-performing students have difficulties in reasoning with representations that do not fully accommodate the fraction as a part-whole concept. In contrast, high-performing students were at ease with a range of representations, including the ones that only vaguely represented the fraction as a part-whole concept. This might imply that the internal mental image of fractions in high-performing students might be richer than the internal mental representation of fractions in low-performing students as it might include extra knowledge about the part-whole concept of fractions.

Although some of the findings may appear retrospectively intuitive, confirming them with data and automating the detection process will enable the provision of more targeted support.

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