Mining students' strategies to enable collaborative learning

Sergio Gutierrez-Santos
London Knowledge Lab
Birkbeck,
University of London, UK
sergut@dcs.bbk.ac.uk

Manolis Mavrikis
London Knowledge Lab
Institute of Education,
University of London, UK
m.mavrikis@lkl.ac.uk

Alex Poulovassilis
London Knowledge Lab
Birkbeck,
University of London, UK
ap@dcs.bbk.ac.uk

ABSTRACT

Despite the benefits that collaborative discussion has on learning, one difficult problem is the formation of pairs or groups that enable appropriate discussion. This problem is even more challenging in the case of unstructured interaction with exploratory learning environments. Building on previous work on supporting individual learners in such environments, this paper reports on a tool that generates groups of students by mining what they have done in the context of an exploratory activity and then calculating similarities between their strategies.

1. INTRODUCTION

Exploratory Learning Environments (ELEs) are educational applications that provide direct access to a domain or to some alternative representation and offer a context and appropriate tools to scaffold the learning experience. They are generally aligned with theories of learning that emphasise the role of learners in constructing their own learning. In parallel to their recent upsurge, there has been a lot of work in the field of Computer-Supported Collaborative Learning (CSCL) with technological advances that are making collaborative problem solving and co-construction of knowledge possible even for remote participants. Research in both areas (ELEs and CSCL) has demonstrated that working in groups has the potential to enhance learning, but that careful planning and structuring of collaborative tasks and strategic formation of collaboration groups is a necessary prerequisite [1, 4].

Although the advantages of encouraging students to examine different approaches to a problem, discuss the benefits and drawbacks of each, build on each other's ideas, and benefit from the reflection that results from interaction with others, have been widely identified [4, 5]), it can be difficult to form *potentially productive* groups i.e. groups that will provide opportunities for students to engage in fruitful discussions, enabling them reflect on their approaches to the problem, to justify and critique their solutions, and thus lead to deeper learning. This is even more so in the case of courses with a very large number of students such as Massive Open Online Courses (MOOCs), where it is infeasible for humans to participate in the creation of the groups and any effectiveness beyond haphazard pairing must be the result of analyzing students' work. Once again, exploratory activities can offer more opportunities due to their richer interaction possibilities.

2. FORMING GROUPS BASED ON EXPLORATORY LEARNING STRATEGIES

This paper reports on a tool that aims at helping to overcome these challenge. Our tool generates groups of students by mining what they have done in an exploratory activity and then calculating similarities between their strategies. The aim is to alleviate teachers/lecturers from the task of grouping students into meaningful pairs; by *meaningful* we mean pairs that maximise the probability that students will have complementary approaches or strategies to a given task or tasks, and therefore will have more opportunities for discussion, reflection, and ultimately learning. Building on former work aimed at supporting individual students [2], this tool was first created in the context of the eXpresser microworld for the learning of algebra [3] but the general principles are valid for any exploratory learning environment that is intended to be used with very large groups. Although we omit the details of the original microworld for the sake of space, it suffices to say that the microworld allows students to create pictorial tile patterns in a square grid, that patterns can be created in many different ways, and that they are used as a scaffold towards different kinds of algebraic and pseudo-algebraic formulations of mathematical problems, thus helping young learners to strengthen their algebraic generalisation skills.

Figure 1 shows three different ways of creating the same pattern and how the same algebraic formula can be expressed in different ways. Typically, in the context of a module several tasks will be tried; for any given task, students will find one solution from the set of possible solutions (advanced students may find several) and its corresponding formula. In a classroom scenario, these individual tasks are usually followed by a collaborative task in which pairs of students must explain to each other how "their" solution is the "right" one and whether their two solutions are equivalent.

It is evident that, in order for this discussion to be meaningful, students in each pair must have found solutions that are quite different; this maximises the cognitive conflict and requires deeper reflection to see the equivalences. Unfortunately, differences in real students' approaches are rarely as evident as in the three paradigmatic solutions shown in Figure 1; even in classrooms with relatively low numbers of students, teachers find themselves in a situation in which they do not have the time to make groups effectively, taking into account all details, and they resort to haphazard cre-

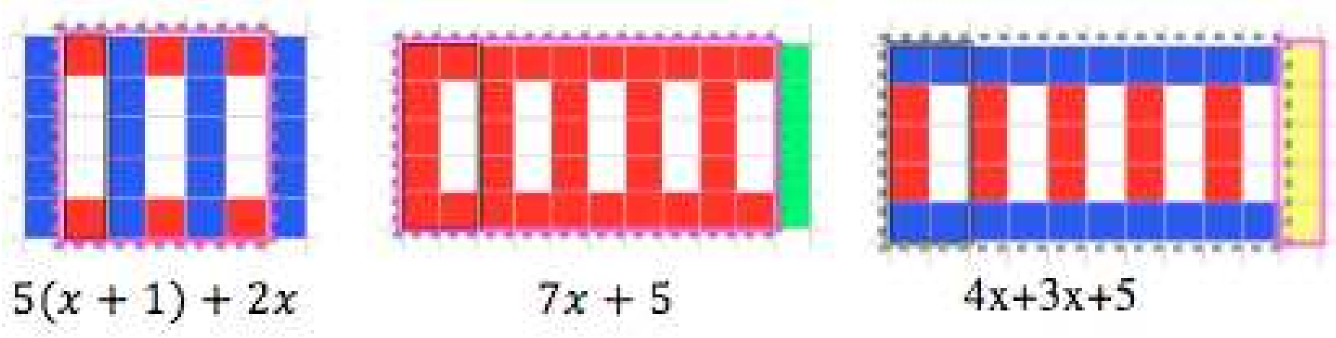

Figure 1: Example of different task solutions. Different constructions of the pattern lead to different (but equivalent) expressions.

ation of groups (e.g. based on the order of task completion or based on student choice). Our tool, on the other hand, analyses the students' actions and then suggests pairs that minimise the similarity among the approaches taken by the two students in each group.

Different strategies. In the first stages of the design of this grouping tool we tried to clarify the limits of the task, namely what were the characteristics of the best group and the worst group in our context. Although it is obviously hard to reach an agreement about these general ideas, all teachers and educators agreed that grouping together two students who have created exactly the same construction (i.e. used the same approach for the task) would not lead to much discussion as there is nothing to compare. Therefore, the first step was the determination of the definition of equality of two constructions. In collaboration with the pedagogical team, we agreed on the following definition: "Two constructions are equal from the point of view of collaborative discussion if they have the same number of patterns, the patterns have the same building blocks, the building blocks are displaced horizontally and vertically by the same amount on each iteration, and any expressions used in their attributes are related using variables in the same way".

The value of starting the design process by defining equality between exploratory strategies is twofold. First, the definition allows us to know when two students should not be put together in the same group. More importantly, it also clarifies the factors that determine when two constructions are different (and how). Our tool represents each student's strategy as the combination of three vectors in three different spaces with different metrics: building block related, numerical, and relationship. Then the overall similarity, s, is calculated as a linear combination of the inverse of the distances between the vectors of one student's strategy and those of the other:

$$s = K \times \left(w_{bb} \cdot \frac{1}{1+bbd} + w_n \cdot \frac{1}{1+nd} + w_r \cdot \frac{1}{1+rd} \right)$$

where bbd, nd, and rd are the total building block, numerical, and relationship distances between pairs of patterns in the two constructions, and the w_x are weights. K is a scale factor related to the number of patterns.

Fine-tuning with experts. Weights w_{bb}, w_n, and w_r were initially set to 0.4, 0.3, and 0.3, following discussion with teachers, but were later modified and fine-tuned to ensure that the calculations made by the tool were in line with the perceptions of teachers about similarity between different students' constructions. We evaluated the validity of the suggestions of the tool by a process of gold-standard validation. This consisted of an iterative process in which our team of pedagogy experts were presented with several scenarios, each of them containing different microworld constructions, and the experts were asked to assess their similarity. At the end of this process, the average agreement between the tool's recommendation and the experts' was higher than 80%.

Acknowledgements. The eXpresser microworld and initial prototypes of the grouping tool were created in the MiGen project (migen.org) funded by the ESRC-EPSRC TEL Programme. The work here has been co-funded by the EU under the FP7 projects iTalk2Learn (#318051) and M C Squared (#610467).

3. REFERENCES

[1] P. Blatchford, P. Kutnick, E. Baines, and M. Galton. Toward a social pedagogy of classroom group work. *International Journal of Educational Research*, 39(1-2):153–172, 2003.

[2] S. Gutierrez-Santos, M. Cocea, and G. Magoulas. A case-based reasoning approach to provide adaptive feedback in microworlds. In *Intelligent Tutoring Systems*, pages 330–333, 2010.

[3] R. Noss, A. Poulovassilis, E. G. an Sergio Gutierrez-Santos, C. Hoyles, K. Kahn, G. D. Magoulas, and M. Mavrikis. The design of a system to support exploratory learning of algebraic generalisation. *Computers and Education*, 59(1):63–81, August 2012.

[4] M. Swan. *Collaborative Learning in Mathematics: A Challenge to Our Beliefs and Practices.* National Institute for Advanced and Continuing Education (NIACE, London, 2006.

[5] P. Vahey, D. Tatar, and J. Roschelle. Using handheld technology to move between private and public interactions in the classroom. In *Ubiquitous computing in education: Invisible technology, visible impact*, pages 187–210. Lawrence Erlbaum, 2007.