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The NISPI framework: Analysing collaborative problem-solving from students' physical interactions

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ABSTRACT

Collaborative problem-solving (CPS) is a fundamental skill for success in modern societies, and part of many common constructivist teaching approaches. However, its effective implementation and evaluation in both digital and physical learning environments are challenging for educators. This paper presents an original method for identifying differences in students' CPS behaviours when they are taking part in face-to-face practice-based learning (PBL). The dataset is based on high school and university students' hand position and head direction data, which can be automated deploying existing multimodal learning analytics systems. The framework uses Nonverbal Indexes of Students' Physical Interactivity (NISPI) to interpret the key parameters of students' CPS competence. The results show that the NISPI framework can be used to judge students' CPS competence levels accurately based on their non-verbal behaviour data. The findings have significant implications for design, research and development of educational technology.

1. Introduction

Collaborative problem-solving (CPS) is a fundamental skill for modern societies to function and it should be supported and practised in Education systems across the globe. Perhaps, as the significance of CPS is clear to most educators, it is part of many common constructivist teaching approaches including problem-based learning, inquiry-based learning, project-based learning, and practice-based learning. It is common to see situations in which learners work in unison to solve a problem during these teaching approaches, and perhaps that is why these constructivist teaching approaches are considered to have the potential to help foster the 21st-century skills we require of young people. For some decades now, there have been strong advocates of these teaching approaches in Education, arguing their merits in achieving such high-tier learning objectives (Barron & Darling-Hammond, 2010; Montessori, 1965). However, existing evidence on the effectiveness of these methods to satisfy their learning outcomes is rare (Klahr & Nigam, 2004), and they have been harshly criticised by some researchers as not being effective pedagogical approaches (Kirschner, Sweller, & Clark, 2006; Mayer, 2004).

According to Blikstein and Worsley (2016), this lack of evidence may stem from these pedagogical approaches' notoriously dynamic and laborious structures and commonly used standardised measurement methods' lack of ability to detect impacts on students' skill development. However, the most recent developments in sensor technologies and learning analytics methodologies can help generate unique information about what happens as groups of students are engaged in constructivist

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pedagogies. Distinctions in student behaviours that can be detected and tracked with such technologies can be used to continuously evaluate and support students during their engagement with constructivist pedagogies. This paper focuses on students' CPS competence in practice-based learning (PBL) activities. More specifically, it presents an original framework to identify observable and objective differences in students CPS behaviours in open-ended, practice-based learning environments.

In order to make better sense of the results of this paper, it is important to make our understanding of CPS clear. Similar to the ideas of Panitz (1999), in this paper, the interpretation of collaboration is more of a philosophy of interaction, in which individual group participants' contribution is well respected and highlighted during the processes of problem-solving and knowledge construction. It is obvious to us that this approach differs from other group work approaches (including cooperation and peer tutoring) that are more formally structured to facilitate the creation of an end product or an aim. It is also different from competition-based approaches in which individuals aim to outperform their team mates. All these different approaches might be valuable to consider for teachers as part of a broad pedagogical repertoire in order to achieve different learning outcomes of various learning contexts.

The rest of the paper is structured as follows: in the next section, what we understand by CPS in the context of this research work is presented, how it can be observed is discussed and some key aspects of CPS to be investigated (namely, synchrony, individual accountability, equality and intra-individual variability) are defined. Section 3 is devoted to the methodology used in this research, including the participants, learning activities and instruments of measure used. Then the results are presented, which is followed by the discussion. The paper concludes with some conclusions and ideas for future research.

2. About collaborative problem-solving

CPS is a term that is increasingly used to refer to the process of a number of persons working together as equals to solve a problem. It brings together thinking and research about the separate topics of collaboration and problem-solving, both of which have a substantial research history in their own right. CPS is more than individual problem-solving in the company of others. It involves a set of sophisticated interaction skills that need to be utilised at the same time in service of supporting, directing, facilitating and coordinating the thinking of others with ones own, to achieve a mutually agreed goal. There is a substantial relevant research literature, going back some 50–60 years, across compulsory and post-compulsory education. This literature has used a range of different but overlapping terms including cooperative learning, collaborative learning, peer co-learning, peer tutoring, peer assisted learning as well as numerous other terms and phrases. Many authors have used these terms interchangeably, while others have tried to be quite distinct in how they define and describe them. Either way, it is very difficult to classify studies with respect to the different approaches referred to by this different terminology. However, it is worth discussing the constituent parts of CPS and ground it within the relevant wider literature concerning the associated concept of collaborative learning.

2.1. A working definition of collaborative problem-solving

At a basic level, the verb to collaborate means to work together, and thus it assumes cooperation because participants agree to work together and contribute to the interaction. Collaboration also assumes social coordination, because participants are sensitive and aware of the contribution made by others and the need to make their contributions pertinent and to coordinate their behaviour. But collaboration is more than this, it also involves participants working in unison as equals and oriented to a jointly agreed goal and often generating ideas that can form the basis for a possible solution or decision. Littleton and Mercer (2013) provide an eloquent account of collaborative learning that highlights some key features. These include that participants are engaged in a coordinated, continuing attempt to solve a problem or construct common knowledge; involved a coordinated joint commitment to a shared goal, reciprocity, mutuality, the continual (re-)negotiation of meaning. The participants are likely to experience a group sense or a feeling of shared endeavour; must establish and maintain inter-subjectivity or recognising that they have a shared understanding about their endeavour; must maintain a shared conception of the task or problem; must engage in inter-thinking: understanding each others plans and actions.

Regarding problem-solving on the other hand, OECD (2010) defines it as “an individuals capacity to engage in cognitive processing to understand and resolve problem situations where a method of solution is not immediately obvious. It includes the willingness to engage with such situations in order to achieve ones potential as a constructive and reflective citizen”. A recent publication by Leadbeater (2016) sees problem-solving as a richer concept in which problem solvers: deploy knowledge in action, to work with others and to develop critical personal strengths such as persistence and resilience, to learn from feedback and overcome setbacks. This assumes collaboration as part of the problem-solving process, but helpfully also specifies the process as involving knowledge in action and overcoming setbacks. This resonates well with Marzano (1988), who has been highly influential on the OECD's definition and more widely in education. Marzano identified four knowledge utilisation processes: decision-making; problem-solving; experimental inquiry; and investigation.

Marzano described the process of problem-solving as happening when a learner attempts to accomplish a goal for which an obstacle exists (influenced by Rowe, 1985). Problem-solving requires the learner to use their existing relevant knowledge about the problem, retrieve prior knowledge, both about the subject matter of the problem and about the process of problem-