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Transactional distance in an undergraduate project-based systems modeling course

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ABSTRACT

Assessing the level and quality of collaboration between students working in project teams is a complex task. The main goal of our study was to develop and validate an online questionnaire for assessing the quality of distance teamwork collaboration in a project-based systems modeling course. The research goals included assessing the transactional distance (TD) perceptions among peer students who had collaborated in jointly constructing conceptual system models of projects carried out by distant researchers and the TD between the students on one hand and the distant researchers on the other hand. The research questions were aimed at validating the TD questionnaire as a tool for assessing TD. The research population included undergraduate students who participated and collaborated via a visualization-based environment as part of the EU VISIONAIR infrastructure project. The students interacted both among themselves and with remote researchers across Europe. Reliability and inter-correlation tests have indicated internal structure validity and reliability of the TD questionnaire. Correlation with other student outcomes indicated content validity by criterion. Experiencing visualization-based environments was a key factor in student satisfaction. Based on our findings and the collaboration literature, TD may serve as an alternative assessment tool for evaluating the quality of collaboration among peer students and researchers.

1. Introduction

Modern engineering education programs aim to endow students with a broad base of knowledge, skills, and attitudes necessary to become successful young engineers [7]. The engineering education goal is to train students to be able to conceive, design, implement, and operate complex, value-added engineering products, processes, and systems in modern, team-based environments. An important consequence of this trend is that beyond the exposure of students to the body of technical knowledge and the product, process, and system building skills specific to their engineering profession, they also need to acquire interpersonal skills and additional personal and professional traits. These insights formed the basis for the CDIO – Conceive Design Implement Operate educational framework [6].

The CDIO approach is designed to raise the quality of engineering education programs [30], and most of the CDIO features are related to experiential learning [6]. This approach emphasizes the importance of active and hands-on learning in both the classroom and modern learning workspaces. CDIO enables students to be exposed to the experiences that they will encounter as engineers during their professional lives. To enable these kinds of experiences, the CDIO syllabus contains significant elements of project-based learning [7].

1.1. The research goal

The main goal of this study was to develop and validate an online questionnaire for assessing the quality of distance teamwork collaboration on carrying out projects in the spirit of CDIO by measuring the perceptions of peer students and distant researchers during their interactions regarding the transactional distance (TD), a key concept of this work, which is explained in detail in the sequel.

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In what follows we present the theoretical background of the teaching and learning methods – project-based learning and collaboration, the assessment method of such collaboration, and the concept of transactional distance.

1.2. Project-based learning

Project-based learning (PBL) is a teaching method in which students are given realistic problems characterized by not having a single correct answer. Guided through a process of analyzing the problem, researching alternatives, arguing for and against them, the students present a recommended solution [22]. Proponents of the PBL method clarify that it provides real-world and real-time learning opportunities that replicate the type of problems students will encounter and solutions they will use throughout their academic and professional lives [12,20].

PBL is characterized by authentic investigation, collaboration among peers, the use of technology to support inquiry processes, and delivery of an end product [26,27,42]. Through their active participation in the project execution process, students are encouraged to form original opinions and express individual standpoints. The project fosters students' awareness of the complexity of systems they would tackle and encourages them to explore the consequences of their own values [48]. PBL was tested at the levels of elementary, junior, and high school, as well as in higher education, and was found to be effective for promoting self-efficacy, meaningful learning, and the development of higher order thinking skills [1,33,44,45]. Collaboration, discussed in the next section, is a key feature of PBL.

1.3. Collaboration

Thomson et al. [46] based their theoretical and empirical definition of collaboration on a comprehensive review of the literature and a systematic analysis of multiple definitions of collaboration across many disciplines. They have defined collaboration as a process in which autonomous actors interact and jointly create rules and structures governing their relationships. They added that collaboration processes involve shared norms and mutually beneficial interactions. Dillenbourg [8] defined collaborative learning as "two or more people [who] learn or attempt to learn something together." Johnson [24] emphasized that collaborative learning pedagogy has shifted the focus from the teacher–student interaction to the role of peer relationships.

Collaborative learning is part of the constructivist approaches, also known as active approaches and student-centered pedagogy theories [19]. Pedagogical methods, including collaborative learning, which build on these theories, create learning situations, such as laboratories, field studies, simulations, and case studies with group discussions, which enable learners to engage in active exploration and/or social collaboration [19]. These theories present learning as a social process that takes place through communication with others. The learner actively constructs knowledge by formulating ideas into words and graphic illustrations, and these ideas are built upon through reactions and responses of others. In other words, Hiltz and his colleagues [19] claimed that collaborative learning is not only active; it is also interactive.

Dillenbourg [8] indicated that collaborative learning mechanisms directly affect cognitive processes. The first of these mechanisms is the conflict or disagreement mechanism, which is based on social factors that prevent learners from ignoring conflict and force them to seek additional information and find a solution. Internalization is another mechanism, in which the concepts, conveyed by the interactions with more knowledgeable peers, are progressively integrated into the learner's knowledge structures. When integrated, they can be used in the student's own reasoning mechanisms. Finally, the self-explanation mechanism is founded on the finding that while less knowledgeable members learn from the explanations of more advanced peers, the more able peers also benefit, because the need to generate and deliver an explanation improves the knowledge of the explainer. Explaining to others may be more beneficial to the explainer when the material is complex than when the material is simple. Such self-explanation processes are the essence of the interactions that occur naturally in collaborative learning.

Based on the variety of definitions and explanations of collaborative learning, we define collaborative learning as a learning process in which learners acquire knowledge and gain understanding via a mutually beneficial explanation process. One of the main principles of CDIO and PBL is the ability to assess and assure the quality of the learning and collaboration process and outcomes [30].

1.4. Assessment of collaboration

Assessment, defined as a collection of information on students' outcomes [38,39], is commonly applied to evaluate students. Alternative assessment is applied to evaluate students on the basis of their active performance in using knowledge in creative ways to solve worthy problems [39]. Embedded assessment comprises recurring activities that are indistinguishable to students from instructional activities, enabling a comparison of students' current understanding with the expectations of the curricular goals [25]. The combination of alternative and embedded assessment can potentially yield a powerful set of tools for measuring learning effectiveness, enhancing learning outcomes [29], and fostering higher order thinking skills [13].

As noted, a main goal of engineering education is to train the engineers of the future to collaborate and work as part of a team. Since assessment is an important part of education processes in general, and since it serves as a means for quality assurance of CDIO in particular [30], it becomes necessary to measure the quality of learning that takes place during peer collaboration.

Although it might be possible to extend the general definition of collaboration of Thomson et al. [46] for collaborative learning, it was not possible to use this definition operationally for measuring the quality of collaborative learning. These researchers claimed that "few instruments to measure collaboration exist, and those that do are difficult to adapt outside the immediate context of a particular study" [46]. Accordingly, they have conceptualized the collaboration process in terms of five dimensions: governance, administration, mutuality, norms, and organizational autonomy. Based on these dimensions they developed a collaboration assessment instrument. The variables and items in this instrument indicate that it measures collaboration between organizations, but it does not measure the mutually beneficial explanation process occurring among the collaborating stakeholders and their learning process outcomes.

In order to measure the effects of collaboration in their newly developed learning environment, Hwang and Karnofsky [23] divided collaboration into three dimensions: collaborative situations, interactions, and processes. For measuring these collaboration dimensions, they observed and inquired about specific uses of their software and hardware, such as patterns of keyboard strokes and mouse movements, patterns of monitor use, and patterns of shared meaning tools. Their operational definition was adapted to their unique environment and related to the use of the environment in the context of collaborative learning. However, it did not measure the mutually beneficial explanation process which assesses the quality of collaboration among the collaborating people themselves.