Visualization-Based Collaboration and Transactional Distance among Students in a Mini-Project in Industrial Engineering Course

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Abstract

Our study is of a pioneering nature, in which we develop assessment techniques, based on Transactional Distance (TD) theory to assess the distance among peer students who participated and collaborated in a PBL- and visualization-based undergraduate course. About 20 students, who participated in a Mini-Project course in Industrial Engineering, constructed conceptual models, expressed in terms of an Object Process Methodology (OPM) for analysis of real projects. The students worked in two groups and had to collaborate with their peers and with an international project team. We used a mixed method and research tools included web-based questionnaires, semi-structured interviews, reflection reports and project summary reports. The findings confirm and reinforce the choice of TD as a theoretical framework for constructing assessment techniques for collaborative project base learning (PBL) involving advanced visualization and distance technologies. Additionally, our undergraduate students expressed high satisfaction from being exposed to and experiencing work in a visualization-rich, project-based environment in a very early stage of their learning.

Subject and Problem Statement

Transactional Distance (TD), developed by Moore (2007), is one of the theories underlying distance teaching and learning. The TD theory proposes that in distance education the pedagogic distance, rather than space or time-dependent distances, is the critical factor to be considered. Following Moore (1993), we define TD as the combination of pedagogic, psychological and communication distances, which may lead to miscommunication and misunderstandings that hinder distance learning.

Distance education occurs between a teacher and students in a learning environment with unique characteristics of separation between the participants and therefore leads to a unique teaching and learning behaviors (Moore, 2007). The physical separation leads to a sense of distance, which opens the door for misunderstandings between the teacher and the students, as well as among student peers. TD is a specific, subjective and personal distance which results from distance teaching experienced and perceived by the people involved. Unlike the common viewpoint, which attempts to apply knowledge and theories from traditional education to distance education, Moore claims that the distance that separates participants apart is critical, mandating that we re-evaluate the educational and pedagogical needs and settings. Giossos et al. (2009) have claimed that expressions such as "You don't understand me" or "You are not following" indicate absence of mutual understanding or shared perception of ideas, feelings, or situations. This is a cause for TD—the outcome of the teaching activity that results in absence of a mutually shared perception of knowledge, thoughts and approaches, as well as differences in psychological and educational needs and feelings.

Adopting the realistic epistemology of Giossos et al. (2009), Wengrowicz and Offir (in press) have suggested that students making an effort to understand the learning materials are influenced by the teaching activity, causing them to feel a subjective distance. The teacher, who tries to help the students understand the material from a distance, is also influenced by the teaching activity, causing her or him to feel a subjective distance as well. Accordingly, these researchers have defined Teacher Transactional Distance (TTD) as a teacher's perceptions of TD. TTD includes a teacher's feelings towards the teaching process, evaluation of one's ability to communicate with the students, and satisfaction from the teaching process in various settings.

TD has been tested in classical distance teaching and learning environments. This study focuses on assessment of TD in emerging project-based and visualization-rich collaborative environments, where the role of teachers and students becomes fuzzy, as it is replaced by peer students, collaborating both with each other and with distant researchers. In this study we examine the students' conceptions as a result of the collaborative distance learning processes based on the students' evaluation of their ability to communicate with their peers and with researchers aboard, to know and explain whether and to what extent they understood their peers and vice versa, and their satisfaction from the collaborative environment in the context of explaining and learning. The research findings are expected to promote understanding of TD among distance learners in project-based and visualization-rich collaborative environments.

Science and technology develop through exchange of information, much of which is presented visually (Mathewson, 1999). Project-based learning (PBL), a teaching method which has been studied quite intensively (Barak & Raz, 2000; Krajcik, Czerniak, & Berger, 1999; Marx et al., 1997; Tinker, 1996) and is used in our research, is characterized by authentic investigation, collaboration among peers, the use of technology to support the process of inquiry, and delivery of an end product (Klein & Merritt, 1994; Krajcik, Czerniak, & Berger, 1999; Polman & Pea, 2001). Paivio (1990) and Mayer (2002) suggested that human cognition is divided into two major processing sub-systems: the verbal and the non-verbal and that knowledge is represented and manipulated through visual and verbal channels. Dori and Belcher (2005) demonstrated how to implement this approach in science teaching.

The main goal of this study is to assess the TD among peer students who participated and collaborated in a PBL- and visualization-based undergraduate course. Research objectives include (1) Developing and implementing assessment techniques for collaborative PBL involving advanced visualization and distance technologies, (2) Mapping the characteristics of TD perceptions of students using various ways to collaborate with their peers and with distance researchers, and (3) Examining relations between TD perceptions resulting from peer collaborative learning and those resulting from collaboration with distant researchers.

Design and procedure

The research was conducted within the framework of the Mini-Project in Industrial Engineering course, which aims to expose 3rd semester undergraduate students to work in a real international project environment by engaging them in constructing jointly a conceptual model expressed in terms of an object-process methodology model (Dori, 2002). All the projects they are working on are part of an EU project aimed at creating an infrastructure for conducting state-of-the-art research in visualization. It offers, among other things, to support research by helping researchers across Europe with the definition, modeling, and subsequent execution of research projects. The

students (n=17) in the Mini-Project course are part of this effort and they were working on two different projects (Project 1, n=7; Project 2, n=10). For data collection, we used the mixed study method and adopted qualitative and quantitative approaches, including web-based questionnaires, semi-structured interviews and content analysis for the written sources. These sources included reflection reports, open-ended responses to questions, project proposals, and project summary reports.

Following Dori and Belcher (2005), who have shown that visualization technologies can support meaningful learning in an undergraduate electromagnetism course at a leading US university, our study adopts a mode of assessment that is commensurate with the new visualization technologies developed and applied within this EU project. We also examined various aspects of the communication and interaction among students and between students and customer researchers abroad via video conferencing of various kinds.

For the purpose of this assessment, we have developed and analyzed a TD questionnaire to assess the effectiveness of using various visualization technologies for collaborative PBL among the undergraduate students. The questionnaire, which was validated by three experts in educational technologies, measures students' perception of TD using three measures: (1) the communication distance (TD-com) which describes the students' subjective feelings regarding their ability to communicate with others and the ability of others to communicate with them while working on the project, (2) understanding distance (TD-under), which describes the students' subjective feelings regarding their ability to explain themselves using a technology learning environment and their ability to know whether others understood them, and (3) the satisfaction distance (TD-sat), which describes the students' subjective feelings regarding their satisfaction from the learning environment of the course, the tools at their disposal, and the manner in which these tools contributed to their ability to collaborate and work on the project. The close-ended part contained 30 items, of which 15 were related to peers TD (PRTD) and 15—to the distant research project's team TD (DTTD). The students were asked to indicate their agreement with the statement on a Likert scale from 1 (agree to a very small extent) to 5 (agree to a very great extent). They could also choose 0 for any irrelevant item.

Internal consistency (Cronbach's alpha) was calculated to determine the reliability of the questionnaire. In this test, the internal consistency coefficient was calculated for all the three PRTD types combined (α=0.89), and for each PRTD type separately ($\alpha_{PRTD\text{-}com}$=0.77; $\alpha_{PRTD\text{-}ubner}$=0.86; $\alpha_{PRTD\text{-}sat}$=0.85). Internal consistency coefficient was calculated also for all the distant research project's team TD items (DTTD, α=0.96) and for each content world ($\alpha_{DDTD\text{-}com}$=0.90; $\alpha_{DDTD\text{-}ubner}$=0.90; $\alpha_{DDTD\text{-}sat}$=0.89). Based on the findings of the reliability test, eight measures were calculated for each participant. The scores ranged from 1 to 5, where a higher score means higher participant's perception of closeness (i.e., perception of a smaller distance).

Independent samples t-tests were conducted to compare TD measures in Project 1 and Project 2 conditions in order to ensure that there are no significant differences between those groups. Then, paired-samples t-test was conducted to compare TD measures in peers and distant research projects' team conditions to examine relations between TD perceptions resulting from peer collaboration and those resulting from collaboration with the distant researchers.

The questionnaires' open-ended part consisted of 12 questions that focused on students' perceptions about distance understanding and collaborative working. In addition, students were asked to write a project summary and reflection report, and to respond to a semi-structured interview. The students' responses were read, reread, and gradually analyzed from a descriptive-

interpretive perspective (Denzine & Lincoln, 2005). In order to establish research trustworthiness, three researchers were involved in data analysis and interpretation, applying investigator triangulation.

Findings and analysis

Table 1 presents the TD measures' means, standard deviations and independent t-test results for differences between the projects groups.

Table 1 TD means, standard deviations, and *t*-test results for differences between groups

	Project 1		Project 2		
TD measure	**M**	**SD**	**M**	**SD**	***t*-test**
PRTD	3.84	.63	3.95	.69	ns
PRTD-com	3.80	.54	3.89	.73	ns
PRTD-under	4.06	1.12	3.91	.75	ns
PRTD-sat	3.80	.80	4.05	.80	ns
DTTD	3.58	.86	3.68	.93	ns
DTTD-com	3.53	.95	3.54	1.26	ns
DTTD-under	3.78	1.03	3.50	.88	ns
DTTD-sat	3.69	.80	3.92	.95	ns

These findings indicate that there were no significant differences in TD measures between the two projects groups, so we can treat both as one research group.

Table 2 presents the TD measures' means, standard deviations and paired samples t-test results for differences between peers and distant research project's team collaboration conditions.

Table 2 TD measures means, standard deviations, and t-test results for differences between peers and distant research project's team collaboration

TD measure	**M**	**SD**	***t*-test**	***df***
PRTD	3.91	.65		
DTTD	3.64	.88	1.75*	15
PRTD-com	3.86	.65		
DTTD-com	3.53	1.12	1.30	15
PRTD-under	3.96	.83		
DTTD-under	3.55	.95	1.97*	13
PRTD-sat	3.96	.78	1.91*	15
DTTD-sat	3.83	.88		

Note. * = $p \leq .05$

The findings in Table 2 indicate that there were significant differences in three of the four TD measures among peers on one hand and between students and the distant researchers on the other hand. The DTTD means were significantly lower than the PRTD in those three measures. The reflection reports and the interviews indicated that peer collaboration characteristics were more flexible than the collaboration with the distant researchers.

TD is influenced by the degree of the structure flexibility (Moore 2007). As the structure is less rigid and more flexible, TD is reduced. Our findings confirm and reinforce the choice of TD as a

theoretical framework for constructing assessment techniques for collaborative PBL involving advanced visualization and distance technologies, which was the first objective of our study.

For assessing the relationship between the TD measures, a Pearson product-moment correlation coefficient was computed. PRTD and DRTD were high and strongly correlated, $r(16)=0.72$, $p<0.01$. Table 3 presents the intercorrelations matrix between the TD measures.

Table 3 Intercorrelations matrix between the TD measures

	PRTD-com	**PRTD-under**	**PRTD-sat**	**DTTD-com**	**DTTD-under**	**DTTD-sat**
PRTD-com	---					
PRTD-under	.50*	---				
PRTD-sat	.76**	.66**	---			
DTTD-com	.47*	.43	.63**	---		
DTTD-under	.36	.62**	.37	.60**	---	
DTTD-sat	.69**	.54*	.96**	.75**	.43*	---

*Note. * = $p \leq .05$; ** = $p \leq .01$*

The matrix in Table 3 indicates high, strong and positive correlation between three PRTD measures and high, strong and positive correlated between three DTTD measures. These finding indicate evident internal structure validity of the questionnaire. They also indicate high, strong, and positive correlation between TD perceptions resulting from peer collaborative learning and those resulting from collaboration with distant researchers.

A stepwise multiple regression was conducted to evaluate the necessary variables to predict students' satisfaction from the course. The predictors were communication and understanding TD measures, the course grade and language level of the student. PRTD-com was entered in the first step. The percent of explained variance was 55.8% and the regression equation reached statistical significance, $F(1,11)=13.87$, $p<0.01$. According to the standardized regression coefficients (β), it appears that PRTD-com made a positive significant contribution to explaining the variance, $\beta=0.75$, $p<0.01$.Thus, as peer collaboration through visualization and conferencing technologies increases, so does the course satisfaction.

DTTD-com was entered in the second step in addition to PRTD-com. The percent of explained variance was 74.3% and the regression equation reached statistical significance, $F(2,10)=14.44$, $p\leq0.001$. According to the standardized regression coefficients (β), it appears that PRTD-com made a positive significant contribution to explaining the variance, $\beta=0.50$, $p<0.05$ and DTTD-com made also a positive significant contribution to explaining the variance, $\beta=0.50$, $p<0.05$ .Thus, the more the peers and the distant research project's team collaborated through visualization and conferencing technologies, the more course satisfaction increased. TD-under, course grade, and language level were not found as significant predictors for course satisfaction.

Contribution to the teaching and learning of science

Our study is of a pioneering nature in that it is the first to investigate Transactional Distance (TD) in a visualization-rich, project-based environment which involves students interacting with researchers rather than with their professors. The environment in which the research was conducted emulates a real setting, in which developers and researchers work collaboratively,

often over continental distances, using visualization and conferencing technologies. Indeed, our students expressed high satisfaction from being exposed to and experiencing work in these environments. This study points the need of tailored pedagogies that are commensurate with emerging technology-rich distance education and research environments.

How the paper will contribute to the interests of NARST members

NARST members are most likely to find this research interesting, as it exposes them to the concepts of TD, to new ways of designing PBL approach for undergraduate courses, and to technology-enabled learning in a PBL environment. In summary, this study is a step further toward showing our community how instructors and their students may adapt and adopt new science and engineering course formats that exploit emerging technologies for the benefit of advancing science education.

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