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Students' satisfaction with an INFIRO robotic direct manipulation learning environment

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ABSTRACT: This article presents the degree of students' satisfaction with a robotic direct manipulation learning environment, which was developed during a European Union founded project INFIRO. By conducting cognitive and conceptual analysis, it was possible to develop a frame of reference for determining students' degree of satisfaction. Research shows that predictors, such as interactions, self-efficiency and self-regulation, are suitable measures which contribute to student satisfaction in open learning systems. Descriptive statistics and analysis of variance was performed to determine the contribution of predictor variables to student satisfaction. The degree of overall students' satisfaction is high (mean = 4.6 on a scale from 1 to 5). The results also showed that learner-instructor interaction, learner-content interaction, and on-line and off-line self-efficacy were good predictors of student satisfaction. Interactions among students and self-regulated learning have to be considered carefully. Learner-instructor and learner-content interactions are indicated as the most significant.

INTRODUCTION

Direct manipulation environments are mind tools [1], educational materials that have the capacity to provoke discourse and higher-order thinking skills, such as analysing, synthesising, evaluating and causal reasoning [2][3]. Robotic direct manipulation environments provide a potentially rich context for learning scientific or technological knowledge [3]. Summer schools of technology education are effective learning pathways in open learning systems [4] and a way to use and test special direct manipulation environments. Open learning refers to there being minimal constraints on access, pace and method of study. The term is often used to encourage traditional institutions to minimise barriers between themselves and aspiring learners. Open learning is an important factor in boosting and developing technological literacy, which is in the domain of the technology education curriculum [5][6].

Technologically-literate students should be able to understand and evaluate/judge/assess technology, and to help consciously and efficiently to transform the natural world into the human environment. Technological literacy can be seen as technological competencies that complement each other; the ability to create, repair and implement technologies, which students learn in the context of technology education [5]. Students are also becoming more technologically literate through robotic problems [3]. In open learning of robotics, direct manipulation environments are often used. As a result of the European Union funded project *Integrated Physics Approach to Robotics Designed Laboratory - INFIRO*, an INFIRO direct manipulation environment was developed.

Academic leaders around the world have indicated that open and distance learning is critical to the long-term growth of their institutions, reporting that the increase in demand for open courses or programmes is greater than that for face-to-face courses. According to previous studies, open learning does not differ considerably from traditional face-to-face classroom learning in terms of learning outcomes [7]. Student satisfaction in open learning remains undiminished when compared with face-to-face instruction [8].

Student satisfaction is an important indicator of the quality of learning experiences [7], especially, where direct manipulation environments of robotics are used [2]. It is worthwhile investigating student satisfaction in open settings, because new technologies have altered the way that students interact with mentors/instructors/tutors and classmates [7][9]. The quality of interaction in open settings may depend, to a large extent, on the technology tools utilised during learning [7][9]. Lack of confidence in using information and communication technology may decrease students' satisfaction during open instruction and, in turn, lower their performance. As opposed to face-to-face instruction, the nature of open learning demands greater responsibility on the part of learners [5][7]. The open learners who are unable to regulate learning efficiently are unlikely to be satisfied [10][11]. This study investigated factors (i.e. interactions, self-efficacy, self-regulation) associated with student satisfaction in fully open learning settings.

The measurement of student satisfaction can be useful to the providers of open learning courses, to help them to pinpoint their strengths and identify areas for improvement. Satisfaction ratings go beyond teaching assessments, which have a narrow focus, to include broader aspects of the student learning experience. To grasp the complexity of that learning experience, it is not enough to know the degree to which students are satisfied, it is important to understand the factors that contribute to student satisfaction [11].

THEORETICAL FRAMEWORK

In this part, student satisfaction and predictors of student satisfaction are investigated.

Student Satisfaction

Student satisfaction can be experienced in a variety of situations and connected to teaching/learning. It is a highly personal assessment that is greatly affected by student expectations. Satisfaction also is based on the student's experience of both contact with the organisation and personal outcomes [12]. Student satisfaction could intensify learning effect at direct manipulation environments [2]. An evaluation is important in open education and it consists of different dimensions being in alignment with the goals of a course or programme. Course grades are often used as an indicator of student achievement in open instruction [7], but affective factors can be as important as cognitive factors in explaining and predicting student learning in open settings [13]. Among the attitudinal constructs, student satisfaction, referring to student perceptions of learning experiences and perceived value of a course, may be particularly worthy of investigation. Student satisfaction is related to several outcome variables, such as persistence [8], retention [7], course quality [14] and student success [15]. High satisfaction leads to lower attrition rates, higher persistence in learning and higher motivation in pursuing additional open courses [8][12].

Education institutions consider student satisfaction to be one of the major elements in determining the quality of open programmes in today's markets [7]. Open learner perspectives provide valuable information about the areas that matter to students and help institutions gain a better understanding of their strengths and challenges in providing open programmes [15]. With data on student satisfaction, course designers, educators and administrators can identify areas where improvement is needed [7][11]. Student satisfaction data can be used also to promote students' degree choice. Furthermore, these data challenge stereotypes of the experiences of men and women in technology education and have implications for how technology education teaching practitioners approach the learning experience of their students.

Predictors of Student Satisfaction

Previous studies have determined factors that influence student satisfaction in open and distance learning environments [7]. The framework of this study was proposed based on the interaction model developed by Moore [15] with the addition of potential variables including self-efficacy and self-regulated learning.

Interactions

Interaction has been deemed one of the most important components in open and distance education due to the computer oriented work and, partially, isolation of instructors and learners [14]. An interaction framework, including learner-learner interaction, learner-instructor interaction and learner-content interaction has been proposed [15]. Learner-learner interaction refers to two-way reciprocal communication between or among learners who exchange information, knowledge, thoughts or ideas regarding course content, with or without the presence of an instructor [14]. Learner-instructor interaction consists of two-way communication between the instructor of a course and learners. Learner-content interaction is a process of individual learners elaborating and reflecting on the subject matter or the course content. In contrast with learner-instructor and learner-learner interaction, only one person - the learner - is directly involved in learner-content interaction [14].

With open learning, new types of interactions were found; namely, instructor-instructor, instructor-content and content-content interaction [7]. Previous research has indicated the positive influence of interaction on student satisfaction in open and distance education [7]. Of the three types of interaction, learner-learner interaction and learner-instructor interaction were investigated more often than learner-content interaction. Learner-learner interaction and learner-instructor interaction seem to be more related to, and predictive of, student satisfaction than learner-content interaction in most studies of open learning [7]. Learner-instructor interaction was the most required interaction in Battalio's summary from several open learning studies [16]. However, the findings are inconclusive. Some studies indicated that the amount of interaction that learners have with the content is most important to student satisfaction in computerised laboratory based learning, in comparison with learner-learner interaction and learner-instructor interaction [7].

Self efficacy

Expanded from the self-efficacy theory in psychology [17], researchers in education have indicated that efficacy beliefs positively influence achievement and persistence related to specific instructional tasks [18]. On-line and off-line self-efficacy (ONOFSE) refers to the belief in one's capability to organise and execute computer-related actions required to accomplish assigned tasks [7]. There are two reasons to include ONOFSE as a predictor of open learning student satisfaction. Firstly, open learning relies on ONOFSE delivery through, which various types of activities take place, such as computer design and implementation, measurements, collaborative projects, communication with instructor or classmates, and so on [7][11]. Technical problems while using the computer, computer based devices and equipment may cause student frustration and dissatisfaction [7][12]. It seems important for open learning learners to possess high ONOFSE to complete required tasks for an open course delivered through the computerised laboratory. Secondly, ONOFSE, as one of the three self-efficacy constructs in computer-based instruction, is less-often addressed than academic self-efficacy or computer self-efficacy. The impact of ONOFSE on student satisfaction is scarce and inconclusive (high school, university), while for primary and secondary school students is significant. ONOFSE is positively correlated with expected outcomes including entertainment, social and informational outcomes [7].

Self-regulated Learning

Self-regulation, originally from psychology, was first defined by Bandura [19]. The central ideas underlying self-regulation are motivation and learning strategies that students utilise to achieve their learning goals. The scope of self-regulation has been expanded to studies in education areas [7][11]. Self-regulated learning refers to the degree to which students metacognitively, motivationally and behaviourally participate in their own learning [20]. Metacognitive processes involve learners' ability to plan, schedule and evaluate their learning progress. Motivational processes indicate that learners are self-motivated and willing to take responsibility for their successes or failures. Behaviour refers to the characteristics of the strategies that students utilise to optimise learning [20]. The importance of self-regulation in student performance is evident in traditional face-to-face learning settings [19] and blended learning settings [13]. Unlike traditional classroom instruction, open learning is student-centred and much self-directed effort is required for success [21]. Although most of the studies have indicated that the ability to self-monitor and self-evaluate at different learning stages is positively related to student performance or achievement, there has been limited research pertaining to the association between self-regulation and student satisfaction. The motivational components of self-regulation are positively related to student satisfaction [21]. Metacognitive self-regulation is positively correlated with student satisfaction at a significant level [10]. This study also focuses on metacognitive self-regulation, because metacognitive processes are considered to be the most critical in self-regulation [20][21].

METHODOLOGY

Robotic direct manipulation environments are used as a learning context. The sample, instrumentation, and procedure and data analysis of this study are described in the following section.

The Sample

The sample of this study was drawn from secondary school students enrolled in summer-session open courses; namely, the INFIRO Summer School (ISS). The first ISS 2012 was held in 17-23 June 2012 and the second one was held in 23-29 June 2013. The venue for the ISS was Rabac City, Croatia. The summer-session courses were one week long. With the permission of, and assistance from, the parents and instructors who agreed to have their students participate in the study, a paper and pencil survey was distributed. All (N = 105) of the enrolled students completed the survey. There were more male (83%) than female respondents (17%). Most respondents were between the ages of 14 and 16 years. Few students were younger than 14 or older than 16 years of age. In ISS 2012, just two of the project countries had recruited participants (N = 44), namely Croatia and Slovenia. In the second ISS, 2013, all INFIRO project countries (Croatia, Slovenia, Turkey and Romania) were involved in open learning (N = 61), with the majority of participants having been recruited from Croatia and Slovenia.

Instrumentation Specification

The survey included 15 questions on three predictor variables and student satisfaction. Instrument development was involved for interaction and student satisfaction scales. Overall student satisfaction is five-point Likert scale with four items that ranged from 1 (*very unlikely*) to 5 (*very likely*). Questions on ONOFSE were developed to measure one's confidence in the ability to be successful in performing certain tasks using computer-based technology. The self-regulated learning scale was adopted from the metacognitive self-regulation subscale in the Motivated Strategies for Learning Questionnaire (MSLQ). The scale is a 3-point Likert scale with four items ranging from 1 (*not at all true of me*) to 3 (*very true of me*). It assesses the extent to which learners used planning, monitoring and regulating strategies during the learning process. Beside this, also open ended questions about judgement, expectations, decision making, behaviour and affective part were included.

Procedure and Data Analysis

The survey was administered when the ISS had ended. A high response rate was obtained because of the direct presence of mentors and survey administration. Data analysis was conducted using SPSS 21. Descriptive analyses were conducted to present the students' basic information and the average scores of predictor sub-variables and student satisfaction. The Levene's parametric test for equality of variances was used. ANOVA was conducted to find and confirm significant relationships with an effect size. Pearson *r* coefficient was used as a measure of linear relationship and Cronbach alpha as a measure of internal consistency. The measure of the effect size was eta squared.

RESULTS

An evaluation of the ISS was based on the evaluation of the ex-post survey, which was administered to students on site, using the paper and pencil method. Figure 1 illustrates average scores of students' satisfaction with the ISS. The satisfaction measure consisted of four questions on five-point scales. The average response to all four questions was above 3 on a five-point scale. Participants of the ISS were most satisfied with the work and approach of mentors and tutors; the weakest point was accommodation and meals where most complaints were about the meals. The overall score was very good to excellent, M = 4.6, SD = 0.39. The implementation (p = 0.00, r = 0.78), the learner-mentors/tutors interactions (p = 0.00, r = 0.49), and the content (p = 0.00, r = 0.51) have significant impact on students' satisfaction.

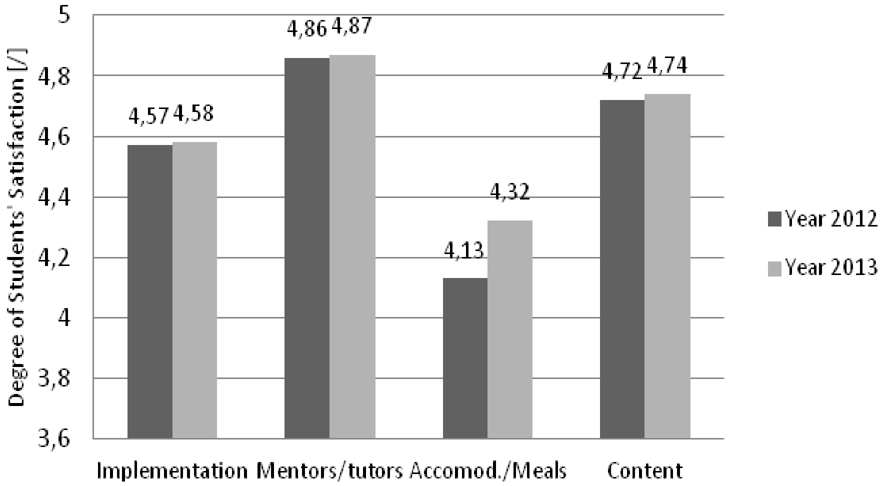

Figure 1: Students' average satisfaction ratings.

Further descriptive analysis indicated that the test for homogeneity of variance was non-significant, meaning that the sample exhibited characteristics of normality required for analysis under the assumptions of the general linear model. The Levene's test for equality of variances achieved no statistical significance, $F(1,103)$ = 0.59 (p = 0.44). The Levene's test confirmed that the study sample did not violate the assumption of normality, which confirmed that the sample is normally distributed. Internal consistency (reliability) of ex-post survey is moderate (Cronbach alpha = 0.74).

Students also expressed their emotional/perceived impressions and opinions. At ISS 2012, students were most impressed with final project implementation and evaluation (32%) and the ISS venue (23%). Workshops and method of open learning were recorded as being of medium value (14%). At ISS 2013, students gained/developed social components (25%) and were impressed by the successful final projects' operation/implementation and evaluation (18%). Students' first impressions did not have an impact on overall student satisfaction. In particular, first impressions have a significant (p = 0.00) impact on the ISS content with a large effect size (eta squared = 0.23).

Participants of ISS 2012 had reported that the mentors (work, approach, willingness to help...) were the most valuable part (71%), also the organisation of the ISS was highly commended (20%) while the venue was rated as low (9%). The situation for ISS 2013 saw changes. The most valuable part were mentors (34%), organisation of the ISS (26%) and the venue was highly rated (23%). Student desired attitude had a significant impact on student satisfaction. The effect size was medium (eta squared = 0.08). This depicts medium learner-mentor interactions. Students completely satisfied with ISS 2012 amounted to 34%, and surprisingly, 16% of participants complained about the free social activities. Some participants wanted to work and to learn more.

A lack of rotation of the groups where everyone could be assigned with electronics and robotics as well (14%) was detected. An extension of work time was also suggested. Also, problems existed with the meals (9%). The work time did not suit 11% of participants. They suggested that the start of workshops to be postponed for one hour and in the evening it uses to be prolonged of two hours. The hottest period of the day should not have work active time. Students also complained about the work place and inadequate air-conditioning (11%). They have noted a lack of modules and components for effective work (5%). A significant impact of negative attitude was recorded in the overall degree of students' satisfaction (p = 0.00). A large effect size was detected (eta squared = 0.25), especially, with regard to the size of short/small scale design and free activities to student dissatisfaction with the content and implementation was indicated.

In contrast, at ISS 2013, the majority of participants were completely satisfied (34%) and 23% of participants were mainly satisfied. A short/small scale design was indicted most frequently as the reason for this. Some participants wanted to work and to learn more. They missed a rotation of the groups so that everyone would be assigned to take electronics and robotics as well. An extension of the work time was suggested. Also, problems existed with the meals, but they were rated higher than in the previous year 2012.

Significant predictors of self-regulation were found:

- Willingness/readiness to participate in the next ISS was indicated in ISS 2012. The majority of the participants (93%) wanted to attend ISS 2013, just 5% of participants were not willing to take part again, while 2% of them were uncertain. The situation at ISS 2013 was similar.
- The level of needs fulfilment at ISS 2012 was notable. The majority, of the students (52%) were completely satisfied (Level 3) with the programme of the study they left, while 46% of the students were mainly satisfied (Level 2). Just 2% of the students were only partially satisfied (Level 1). For ISS 2013, the situation was similar. The majority, 51% were completely satisfied, while 46% of the students were mainly satisfied. Just 3% of them were only partially satisfied. A level of needs fulfilment has a significant impact on student satisfaction ($p = 0.00$). A large effect size (eta squared = 0.28) was detected. In particular, needs fulfilment has a significant impact on the implementation, content and accommodation categories. Effect size was medium to large (eta squared = 0.13).

When participants were questioned about their views on cooperation with other participants, the positive aspects were: friendship, collaboration, sharing new ideas and socialising. The following are two predictors that have been used for assessment:

- Entertainment and social part. At ISS 2012, the majority (80%) of the participants of the ISS confirmed the entertainment component as medium (Level 2). Just 2% of participants argued that the entertainment was not enough (Level 1). At ISS 2013, the majority (79%) of the participants of the ISS confirmed the entertainment component as moderate (Level 2). Just 6% of participants argued that the entertainment was not sufficient. The entertainment and complexity of the ISS do not have a significant impact on students' satisfaction.
- Availability of free time/activities. At ISS 2012, the majority of participants (75%) reported that the ratio between free time and work time was just about right, while 18% of participants confirmed that there was insufficient free time. At ISS 2013, the majority of participants (61%) assessed that there was the right distribution of free time versus work time, while 23% reported insufficient free time. Free time activities have a significant ($p = 0.04$) impact on student satisfaction. The effect size was medium (eta squared = 0.06).

Concerning the impact of the ISS on students' professional practice, some of transferable deliverables were indicated. Participants' opinions about their professional aspects are shown in Figure 2. At ISS 2012, programming knowledge and skills (32%) were perceived as very useful for further study. This is surprisingly very high and this behaviour is more typical for summer schools of computing. Participants argued that professional knowledge of electronics and robotics (30%) would be transferable for future study and work.

Also, 11% of participants described improved workshop skills and experience as a positive result for future work. All deliverables were seen as useful by 18% of participants. At ISS 2013, participants argued that professional knowledge of electronics and robotics (33%) and programming knowledge and skills (28%) would be very useful for further study. Also, 18% of participants said they gained workshop skills and experience as a positive result for further work. A surprisingly high proportion indicated nearly zero use (13%), while just 8% of participants elaborated a full mode of use.

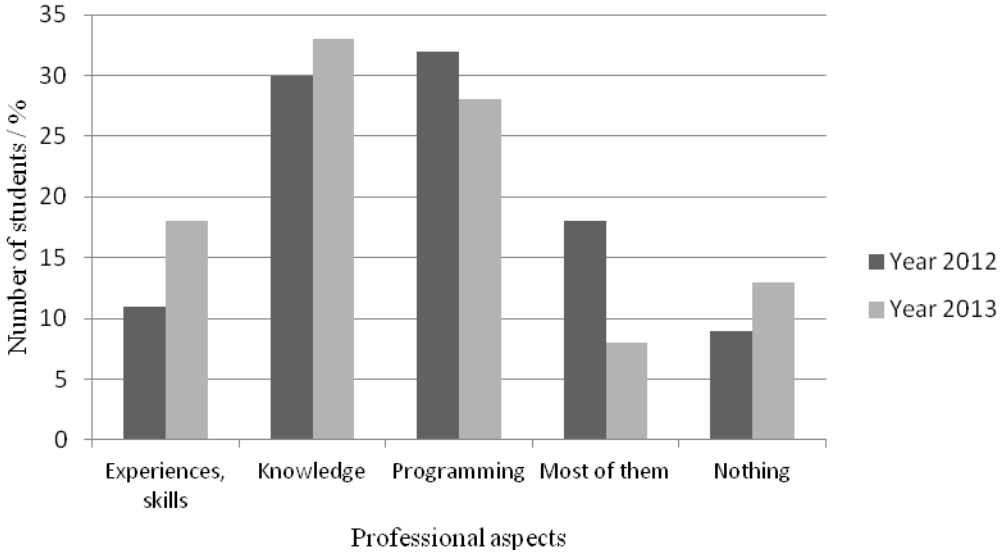

Figure 2: Participants' opinions about their professional aspects.

Complexity/difficulty measure is related to the performance of some attributes. At ISS 2012, Just 4% of the students marked it as complex (Level 3), while the majority (89%) of the students had assessed the ISS as being of medium difficulty (Level 2). At ISS 2013, 12% of the students indicated it was complex, while the majority (72%) of the participants assessed the ISS as being of medium difficulty.

Participants were also asked how the ISS professional aspects had already been introduced into their practice. Possible novel activities were designed (measuring electric current, voltage comparator, soldering, R-S flip-flop, Bascom, voltage measuring, a-stable multi-vibrator, transistor usage, electric circuits simulation software, team/pair work). In ISS 2012, one-third of students were not so familiar with the ISS professional features/content. This group of students was insufficiently assigned to electronics and robotics in secondary school. Just 12% of participants felt very familiar with the ISS design, while 18% of participants represented a group of beginners. The rest of the participants were already acquainted with more than half of the ISS features (54%). They had experience with electronics and robotics as optional subjects at secondary school and this information was useful for workshop group design to improve the efficiency of the workshops.

High recorded variables were indicated, namely Bascom language programming (19%), voltage comparator (12%) and voltage measuring (11%). It can be concluded that a good target group was established for piloting ISS 2012. Participants from Croatia and Slovenia possessed at least a basic to medium knowledge of electronics and robotics, with some advanced exceptions. At ISS 2013, there were two remarkable groups of students. The first group, comprising of 25% of students was already acquainted with all of the ISS professional features/content. This group of students had already been assigned with electronics and robotics as optional subjects at secondary school and this information was useful for workshop group design to improve efficiency of the workshops. The second group of 29% of participants, represented the majority for whom the listed features were novel. Some students (15%) were very beginners in the ISS, which was in line with the design of the INFIRO purpose. It can be concluded that there is a good balance between the learning and training content.

Participants also reported how the organisation of the social/sports activities was. The majority of students were completely satisfied (89%). A lack of social games was recorded by some respondents. Concerning the uniforms (t-shirts), participants were mainly satisfied.

Some marketing issues about the ISS were also investigated:

- Information channel/path. The majority of participants were informed about the ISS at school (teachers, pedagogues, etc). Also, Web information about the ISS was available via national technology and engineering associations, and some of participants were also informed by friends and parents.
- Decision-making factors for the ISS attendance. Most participants were very interested in the ISS, because of personal interest and the ISS professional content. Parents and friends also have a significant impact on students' decisions for taking part in the ISS.

CONCLUSIONS

The purpose of this study was to investigate students’ satisfaction with the INFIRO robotic direct manipulation learning environment as a measure of lesson-course and learning quality. It has been found that students' overall satisfaction level was high, with a mean = 4.6 on a scale from 1 to 5 (standard deviation = 0.38). This indicates very good to excellent INFIRO design and implementation. Investigation was also oriented to student satisfaction predictors where statistically significant and valid confirmation was found.

Learner-instructor interaction, learner-content interaction and on-line-off-line self-efficacy were statistically significant predictors of student satisfaction in fully open learning settings, while learner-learner interaction and self-regulated learning did not predict significantly student satisfaction. Learner-instructor interaction was the strongest predictor among those significant predictors of student satisfaction. The importance of the interactions in open learning was confirmed.

Analysis of the ratings given to the implementation of INFIRO Summer School, physical learning environment, professional didactic/learning material and mentors/tutors showed that satisfaction with the physical learning environment is a critical dimension of students' overall satisfaction. Providing students with a more comfortable physical learning environment (accommodation, meals, workshops, etc) should promote higher satisfaction ratings. Further, focusing on high quality instructions and creating opportunities for students to develop their analytical skills could also help institutions to maintain high level of student satisfaction.

The practical implications of this study are that both instructors and course designers should pay attention to content design and organisation given that learner-instructor interaction substantially contributes to student satisfaction. Instructors should pay attention to students and provide feedback to students in a timely fashion or encourage students to ask questions through different mechanisms. Implementing a technology training orientation before open courses start may help increase students’ confidence in performing on-line-off-line-related tasks required by the course and, in turn, may enhance student satisfaction. Gender seems to be good indicator of the amount of interaction among learners. Instructors are encouraged to design more collaborative activities in primary and secondary school courses to enhance learner-learner interaction. Time spent on-line/off-line may inform instructors about students' on-line-off-line self-efficacy and self-regulation level.

Further research is required to replicate these findings amongst the other samples/target groups, and to identify whether there are specific variations in teaching practices that are particularly salient to the satisfaction of female students. Furthermore, future research should also explore the possibility that these results could be explained by gender differences.

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