Teaching physics in Vietnam: Integrating constructivist and sociocultural learning principles with ICT

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Abstract

Vietnam's Ministry of Education and Training has introduced educational reforms that require Vietnamese teachers to acquire new understanding and skills using information communication technology (ICT) to support teaching. However, there was little literature to guide Vietnamese teachers on how to achieve these goals. The research goals were to implement a theoretical pedagogic model to integrate constructivist and sociocultural learning principles with ICT for teaching physics, and test whether the model would increase interaction within the learning environment, and improve students' physics test results and critical thinking skills. This research was conducted in a Vietnamese context. Data collection methods included student interviews, physics tests and critical thinking skills tests. The result of this study showed that the use of ICT informed by the model can enhance interaction in the learning environment, and students' physics test performance and critical thinking skills. This study can provide guidance for the current strategy of implementing ICT into education. At a global level there is little searchable research on the integration of ICT in teaching physics in Vietnam. The current study contributes to the literature by providing insights into the use of ICT in teaching physics in the Vietnamese context.

Keywords: Constructivist, sociocultural, ICT, learning, teaching, physics, optics

Introduction

In order to support industrialising and modernising the nation, to fulfil the learning needs of Vietnamese people and the requirements of globalisation Vietnam's Ministry of Education and Training (MOET) has implemented primary, secondary and tertiary educational reforms. One of the objectives of the reforms is to implement information communication technology (ICT) into teaching and learning and innovate teaching and learning methods.

Vietnamese teachers are now facing the challenges of technology-driven education. The critical need for teachers in this context is to acquire new understanding and skills in using ICT to support teaching in the light of a student-centred approach (Harman & Nguyen, 2010). However, there is very little literature to inform Vietnamese teachers on how to use ICT underpinned by a student-centred approach in their teaching context.

The current research investigates a theoretical model that supports teachers/lecturers to implement ICT into their teaching. The model employs sociocultural and constructivist principles to enhance interaction within the learning environment, and improve students' critical thinking and learning in the field of physics.

Many Asian countries are strongly influenced by Confucian philosophy (Chang, Faikhamta, Na, & Song, 2018). This includes Vietnam. From the Confucian perspective, teachers hold superior social positions, and it is considered that they provide students with academic truth. Pham (2010) argues that the Confucian influence leads to Vietnamese students tending to behave as passive listeners in classes, and that a learning style including cooperation and interaction is not suitable for Vietnamese students. If the current research suggests pursuing an interactive learning style, the influence of the Confucian model on Vietnamese culture will be a significant challenge when introducing and making this learning style worthwhile for learning and teaching practice.

In this paper the theoretical model and research methodologies are explained. The paper then presents findings about how the implementation of this model affects Vietnamese students' learning. The paper concludes with a discussion of how the model's implementation benefits learning, and whether the model works in a Vietnamese context under the Confucian influence.

The theoretical pedagogic model

ICT is defined by UNESCO as forms of technology used for creating, displaying, storing, manipulating and exchanging information (Meleisea, 2007). This broad definition includes all forms of ICT. ICT today is commonly thought of as relating to electronic and digital forms of technology such as computers, networks, email, internet, telephone, television, radio, and so on. The relationship between learning and ICT is presented in a theoretical framework named the Pedagogic Model of Integrating Constructivist and Sociocultural Learning Principles with ICT (the CSI model – see Figure 1). In this model learning is located in the centre. In general, the nature of learning can be explained by sociocultural and cognitive constructivist points of view: learning occurs in social contexts (sociocultural theories) and entails individual creation and organisation of knowledge (cognitive constructivism).

A sociocultural learning principle: Learning occurs in social contexts

According to the sociocultural view learning occurs in social contexts. This principle relates to the meaning of learning identified by Salomon and Perkins (1998): social mediation as participatory knowledge construction. It is also based on the notions of distribution of cognition and situated learning

Cognition (that is, intelligence or knowledge) is distributed across social systems among people, learners, cultures, artefacts, environments and situations (Pea, 1997; Salomon & Perkins, 1996; Salomon & Perkins, 1998). It is argued that cognition is accomplished rather than possessed by individuals participating in learning activities (Pea, 1997; Salomon & Perkins, 1998), and "learning is participation in social practice" (Greeno, 1997, p. 9). In other words, cognition or intelligence is achieved by participating in social activities.

According to Pea (1997), the distribution of cognition has two dimensions: social and material. The social distribution of cognition relates to the cognition constructed by participating in organised social activities such as working in groups to accomplish shared goals. In this outlook learners acquire knowledge and skill when they participate in social practices (Cobb & Bowers, 1999; Greeno, 1997; Salomon & Perkins, 1998). Therefore, "discussion of alternative arrangements for learning needs to include consideration of the values of having students learn to participate in the practices of learning that those arrangements afford" (Greeno, 1997, p. 10). The material distribution of cognition concerns the cognition constructed by utilising artefacts to accomplish activity goals. Thus, when designing learning tasks for students, sociocultural educators are concerned with designing activities that give students opportunities to participate and work in groups. The students interact and collaborate with each other when they conduct the learning task, and co-construct their knowledge and skills.

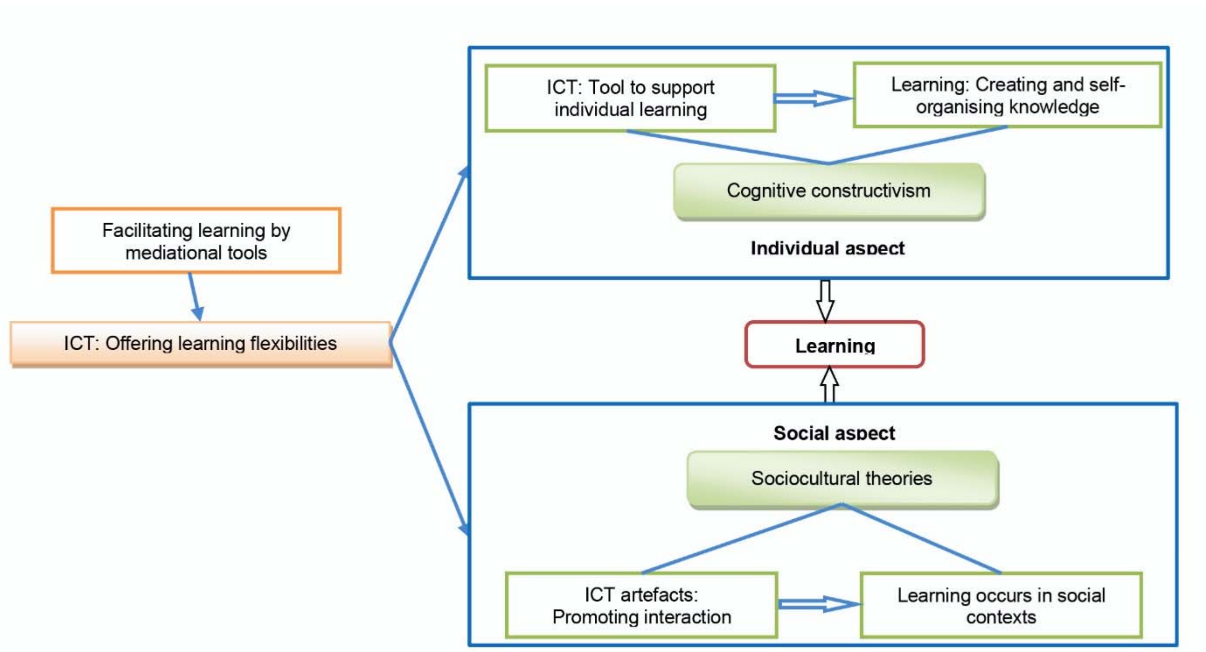

Fig. 1 The CSI model

Reinforcing the view that learning is facilitated by participating in social practices (Cobb & Bowers, 1999; Lave & Wenger, 1991) is the idea that "knowledge is situated, being in part a product of activity, context, and culture in which it is developed and used" (Brown, Collins, & Duguid, 1989, p. 32). Besides the notion that learning is situated in contexts and activities, cultural views also emphasise interactive activity systems in which learners interact with other people (for example, learners, teachers and tutors), as well as artefacts (for example, tools, ICT and learning resources) (Cobb & Bowers, 1999; Cole & Wertsch, 1996; Greeno, 1997).

ICT facilitates learning in social contexts

Learning is facilitated by mediational tools, such as signs, diagrams, virtual reality, language, experimental equipment, technical tools and technology (Daniels, 2008), which enhance learning processes. They may direct thinking and shape actions. Mediational tools will stimulate learners to construct their own knowledge in a social context if teachers use the tools effectively.

ICT as an artefact may promote interaction and facilitate the co-construction of knowledge in social contexts. It is considered that interaction in this model contains interactions between students and teachers, students and other students, and students and learning materials and learning tasks.

Flexible learning environments are commonly thought of in the context of distance learning, yet flexible learning relates to many different choices for students, such as time, place, topics and learning materials. The place where learners contact teachers and other learners is just one dimension of flexibility.

Collis and Moonen (2001) state that flexible learning involves a variety of options for learners in the learning environment. ICT is used to diversify options for students in terms of learning resources, instructional organisation of learning and communication. In addition, ICT is applied to support learners' choices of social organisations of learning and languages.

Learners are provided with a wide range of learning resources, including traditional resources (for example, textbooks and library resources) and ICT resources (for example, educational software, apps, games, videos and virtual reality). Students can be provided with opportunities to access unlimited online resources created by scientists, experts, lecturers, peers and communities. These resources are rich as well as variable in format (for example, texts, photos, diagrams, animations, 3D, augmented reality, audios, videos and virtual reality). Students have opportunities to interact with the learning resources and exploit these ICT artefacts to engage in meaningful learning activities and co-construct knowledge (Pea, 1997; Salomon & Perkins, 1998).

The instructional organisation of learning becomes more flexible when face-to-face interactions, course management systems and computer-based testing systems are integrated by providing learners with many alternatives for submitting assignments and interacting within a course. Software and technology tools are implemented in face-to-face classes. This integration allows learners to decide the pace of study, and choose the instructional mode of learning (for example, face-to-face and online) and the time and place to contact teachers and other learners (for example, in classes at fixed times or off campus during weekdays). Moreover, the application of ICT gives students choices in terms of methods and technology for obtaining support and making contact. The communication can be synchronous or asynchronous. This flexibility provides opportunities for teachers and students to promote discussion and interaction (Jonassen, Carr, & Yueh, 1995), and thus a supporting environment for collective learning (Thomas & Brown, 2011).

Students' knowledge is constructed when they achieve shared goals. Students learn by participating in interactive social systems in which individuals interact with each other and artefacts, including learning resources designed by teachers and others (Greeno, 1997; Salomon & Perkins, 1996). The flexibilities of ICT in terms of communication, instructional organisation, time, place and social organisation of learning can help to promote interaction and discussion within the interactive social systems, therefore enhancing students' learning.

Constructivist learning principles

Learning consists of two aspects: individual and social. The nature of learning from the individual perspective can be explained by cognitive constructivism. From a cognitive constructivist perspective, learners create and self-organise their own knowledge in order to learn (Fosnot & Perry, 2005; Von Glasersfeld, 1989). This principle concerns the human internal process of constructing knowledge. Learning generally begins by observing or experiencing, and continues by making meaning and relating current experiences to cognitive systems that learners have previously developed. Learners then integrate or differentiate the new knowledge, and thus a new balance in their cognitive system is formed. Teachers can facilitate student learning by offering them as many opportunities to observe and experience as possible in a learning context (Watts & Pope, 1989). Teaching should consider learners' prior knowledge (Driver & Oldham, 1986; Ozkal, Tekkaya, Cakiroglu, & Sungur, 2009). Teachers need to provide appropriate help so that learners can relate new information to prior cognitive systems, then make the change and enrich their understanding.

ICT is a tool to support individual learning

From the cognitive constructivist point of view, ICT is a tool for learners to individually construct knowledge. Learning from the cognitive constructivist perspective is a process of self-organising knowledge. In this process, learners experience, assimilate, accommodate and then gain a new equilibrium of cognition. ICT offers rich learning material and resources that can help learners to observe and make sense of new phenomena and experiences in a supportive environment.

Jonassen, Carr, and Yueh (1998) point out how ICT tools such as search engines, hypermedia and visualisation tools can assist learners to construct their knowledge. They argue that with the huge volume and escalation of information, it is necessary for learners to have a tool that supports them to access and process information. Search engines can help learners to access and locate the information sources (websites) that are appropriate for their needs. Websites in general present information in many forms, including text and visual formats (for example, photos, diagrams, and videos). Jonassen et al. (1998) note that learners internalise more information through their visual modality than other sensory modalities. Therefore visual tools, such as colours, photos and videos, assist learners to construct their own knowledge.

Furthermore, information in websites can be organised in linear or hypermedia structures. The link structure enables information to be organised in structured forms that show meaningful relationships between/among groups of information. Through these links learners can navigate the information resources, learn the organisation of the information sources and organise/reorganise their own knowledge. Many hypermedia websites allow learners to add and modify the content and links in the websites. By modifying and creating hypermedia websites and content, learners reflect their understanding of the knowledge and the organisation of the knowledge.

In the context of constructivist learning principles, ICT can also provide students with opportunities to construct their knowledge in symbolic forms (for example, words, diagrams and photos) and organise the knowledge in structured systems (for example, mind maps, structured folders and databases) (Salomon, 1998). Jonassen et al. (1998) hold that ICT visualisation tools assist learners to reason visually and convey their mental images. For instance, software that is used to draw mind maps (for example, MINDMAP, SmartDraw and FreeMind) can be an effective tool for students to organise ideas and refine the organisation of the ideas.

Research methodologies

The research goal is to investigate the implementation of a theoretical pedagogic model for integrating constructivist and sociocultural learning principles with ICT for the teaching of physics in the Vietnamese context.

The research questions are:

1. In what ways does the application of the pedagogic model increase interaction within the learning environment?
2. Does the application of the pedagogic model enhance students' critical thinking skills?
3. Does the application of the pedagogic model improve students' physics test results?

Research design

Quasi-experimental research was used in this study. The student-centred approach, supported by ICT and underpinned by sociocultural views, was implemented by a lecturer in an undergraduate optics course of a physics department within a school of education at a university in Vietnam. The course was delivered over 16 weeks (one semester), including one week for orientation and one week for the examination.

With the support of the researcher, the lecturer designed teaching strategies and learning tasks for his students. The classes were divided into small groups, with about five students in each. Students formed their groups and chose members by themselves. The lecturer required the groups to research optics topics and present the topics in front of the class using Microsoft PowerPoint (MS PP).

The content of the optics course was covered in a book of readings. This book of readings had been designed by the lecturer and evaluated by a faculty committee. It was then revised and used as a textbook for optics courses provided by the faculty. The optics content of the course was organised into 10 topics, including an optional topic, as follows:

The research questions are:

Topic 1: Introduction.
Topic 2: Interference.
Topic 3: Diffraction.
Topic 4: Geometry Optics.
Topic 5: Polarisation.
Topic 6: The Transmission of Light.
Topic 7: Thermal Radiation.
Topic 8: Quantum Optics.
Topic 9: Non Linear Optics.

Each small group was asked by the lecturer to research an optics topic that would be discussed in the next class. The students then divided the work among group members and used a range of sources for the information (for example, textbooks, books and online resources). Each group then organised the information into MS PP slides and designed a presentation to explain the optics topic in the coming class.

It was compulsory for each group to have their learning material for each topic in the form of MS PP slides ready before each class. In class the lecturer asked students from each of the groups to explain the optics topic to the whole class. The lecturer and class then asked the presenting group questions, which was followed by a discussion on the optics topic. The lecturer also supported the students' optics learning through a series of questions and explanations.

Students' learning was supported by a learning management system (LMS). This LMS allowed students to upload and share their learning material, including MS PP slides, and communicate and have discussions online, both in their small groups and with the whole class. The main learning activities that occurred using the LMS included:

- groups of students developing the information that they needed for their presentations
- students submitting their optics presentations and sharing the presentations
- students' forum discussions with the guide of the teaching assistant
- links directing students to optics websites.

There were two groups of students involved in the research: Group 1 and Group 2. Most of the students were in the second year of their university programmes. Students enrolled in the groups based on their study timetables. This allocation might result in differences in optics knowledge between the two groups - however, the differences could be identified by the pre-test on optics.

The CSI model was implemented in both groups, with one difference in the application:

- Group 1 used an online LMS for its optics study
- Group 2 did not use an online LMS for its optics study.

Both quantitative and qualitative methods were employed in this research. The four data collection instruments used were optics tests, critical thinking skills test, questionnaires, and interviews to collect and triangulate the data. Tests consisted of a pre-test and a post-test on optics and critical thinking skills. The students were administered questionnaires at the beginning and end of the semester. Unstructured interviews with groups of students were conducted, mainly at the end of the semester.

Table 1. Data collection and analysis methods address research questions

Research questions	Data collecting and analysing methods
1. In what ways does the application of the pedagogic model increase interaction within the learning environment?	Interview.

2. Does the application of the pedagogic model enhance students' critical thinking skills?	CCTST: t-test, Cohen's d. Questionnaire: descriptive statistics and graph.
3. Does the application of the pedagogic model improve students' physics test results?	Optics test: t-test, Cohen's d. Interview.

An overview of the data collection method, the analysis and the research questions is provided in Table 1. T-test and Cohen's d were used to analyse data for the tests and some parts of questionnaires, while descriptive statistics and graphs were used for most questions in the questionnaires (Cohen, Manion, & Morrison, 2011; Muijs, 2004; Walliman, 2006). The interviews were coded. The codes were categorised into nodes (Cohen et al., 2011). Finally, the conclusion was developed and the research questions were discussed.

Quality assurance

Different quantitative methods were used to measure and investigate the effects of the CSI model on the students' learning, as well as assist triangulating and supplementing the data. Furthermore, a qualitative data collection method – interview – was also used in this phase of the research to help enrich and triangulate the data.

Interview

Five student focus group interviews were performed. Of about 90 students who participated in this research, 36 students were interviewed. Student focus group interviews were employed in this case in order to encourage students to engage in a rich discussion about the topic/question in groups. In this way, diversified perspectives on a topic/question might be presented and discussed deeply among students during the interviews. One of the drawbacks of focus group interviews is that while some students dominated the discussions, others did not talk much. To overcome this drawback, the researcher encouraged the students who did not have the chance to present their ideas by directing questions to them.

NVivo software, which supports qualitative data analysis, was used to analyse the interview data. Each interview was divided into small segments comprising one or more sentences. A segment was then coded into free nodes (open codes) that reflected the content of the segment. At the beginning of this coding process, a block of text was coded independently by two researchers. The codes (nodes) were then compared, and a discussion between the two researchers was generated in order to improve the coding process.

California Critical Thinking Skill Test

To assess students' critical thinking skills, this research used the California Critical Thinking Skill Test (CCTST) purchased from Insight Assessment. The test, containing 34 multiple-choice questions, assesses critical thinking skills that are measured through the scores of five individual scales: analysis & interpretation, inference, evaluation & explanation, inductive reasoning and deductive reasoning. The reliability and validity of the test were ensured. Internal consistency reliability of CCTST KR 20 ranges from 0.78 to 0.82 (reliable).

Three kinds of validity of the CCTST were ensured by the research group at Insight Assessment. Content validity was addressed by designing the test items based on definitions and descriptions of critical thinking skills and subskills from research of the American Philosophical Association. Construct validity was reassured by considering many aspects, such as excluding social class and sex-role contexts, reviewing by independent researchers, and proving the increase of learners' CCTST scores after attending critical thinking courses and training programmes. There are two types of criterion validity: predictive validity and concurrent validity. Predictive validity is defined if the test can predict theoretical expected outcomes - the CCTST scores significantly positively correlate with predicted graduate performance. Concurrent validity refers to the extent to which the test agrees with other tests - the CCTST scores strongly correlate with the scores of other critical thinking and higher order reasoning tests (for example, GRE total score: $r = 0.719$, $p<0.001$ and GRE analytic: $r = 0.708$, $p<0.001$). The staged process of translating the test into Vietnamese is also pertinent to the validity of the Vietnamese version of the test. The process of translating the test contained six stages:

1. Translation of the test into Vietnamese.
2. The Vietnamese translation of the test was reviewed by three Vietnamese lecturers.
3. Independent translation of the Vietnamese version back into English.

4. Revisions to the Vietnamese version of the test requested by Insight Assessment.
5. Revision of the Vietnamese version.
6. Approval by Insight Assessment of the final version.

Physics test

The optics test is a norm-referenced lecturer-developed test that is used each semester when this class is taught. The test was designed by the optics lecturer based on the course outline in order to: (1) evaluate students' optics knowledge and understanding; and (2) compare a student's performance before attending the optics course with their performance after attending the course. There are 40 multiple-choice items in the test, which cover the domain of optics content provided in the course. The same optics test paper was used for the pre-test and post-test.

Findings

Interaction

Data from the students' interviews revealed that the research course (the optics course) was more interactive than other courses.

> I think the interaction between teacher and students in this optics course is more interactive than other courses that I have studied. It is because in the other courses the lecturers talked most of the time, and the students listened and hardly had opportunities to talk or present our ideas. (SI_AGW15)

In addition, the degree of interactions with the learning environment of the optics course also increased during the semester. The interactions within this learning environment can be divided into three types: students–students interaction, students-learning material interaction and students-teacher interaction. From the analysis of the students' interviews, themes related to how these types of interaction occurred within the learning environment emerged. The following sections narrate students' stories through the emerging themes and types of interaction.

Students–students interaction

Student interview data showed there was a wide range of ways the students interacted with each other. For example, they worked in groups outside class, and discussed and carried out learning tasks. They shared the workload among group members in order to complete their learning tasks. Other examples of students–students interaction are in class discussion, exchanging ideas and solutions for assignments, explaining optics topics to their peers and online discussions.

The students were given learning tasks (for example, preparing presentations to explain optics topics to their classmates). They worked in groups and had group discussions to prepare for the presentations.

> It is because the lecturer asks us to prepare the presentations in groups, we discuss [with each other]. For other courses we don't need to prepare presentations and work in groups. So we don't discuss. (SI_AGW14)

The students also noted that they shared the workload. For example, if their group was going to present a topic on optics, the topic contained 10 optics lessons and there were five students in the group, group members decided each person should do the research for two optics lessons. One member of the group then combined the work of the whole group.

> [We divide the workload] equally. For example, if the topic has 10 lessons and our group has 5 members, each of us will have 2 lessons. Then there is a person to combine the work. It is similar for assignments. We divide the assignments equally among us. (SI_AGW14)

In class, the students also explained optics topics and solutions for assignments to their peers. They asked questions and shared ideas. In this way the students thought that they saved time for studying and understood optics in more depth.

> The second strong point is assignments. Each group explains an assignment. This helps to save time. We have many groups, so we can discuss the assignments. If we don't understand an assignment we will exchange and discuss . . . If a group doesn't know [how to solve an assignment] they can ask other groups. (SI_MGW14)
> I work on the presentation one time, then listen to the presentation of classmates one time and listen to the explanation of the teacher once more. Therefore, the optics knowledge is more in-depth compared with other courses. (SI_AGW15)

Students–learning material interaction

According to the students, by working on the learning tasks given by the lecturer they needed to do lots of reading and researching. In this way they could learn more.

> The lecturer requires us to prepare a presentation for each topic. This helps us learn more and learn all of the content. (SI_AGW7)
> [I] go to a physics web page, read and research the content. [I] read and find something related to the lecture notes and something the lecture notes do not explain clearly. [I] look for it and read it. (SI_AGW14)

Students–teacher interaction

The students felt that the degree of students–teacher interaction was high in the optics course. They stated that they had more opportunities to discuss things with this lecturer compared with other courses. The lecturer usually asked questions in class. The purpose of these questions was to guide the students to think and explain the optics topics to their peers. The students contributed to the discussion in the class and so co-constructed their knowledge of the topics. If the lecturer felt that the topics were not fully explained by the students, he would provide further explanations.

> I like [the course] because I have more opportunities to discuss with the lecturer. (SI_AGW14)
> The teacher asked students questions to help students understand the topic . . . [if] they could not explain to each other, he would explain. Not like other teachers. (SI_MGW14)

ICT promoting social interaction

The students used ICT to support face-to-face presentations. From these students' point of view, using ICT helped to attract their classmates' attention and make learning enjoyable.

> When teaching with ICT, we have photos and video clips. This attracts students' attention. (SI_AGW15)

> PowerPoint presentations help students study more easily, help reviewing lessons become relaxing and enjoyable, make learning more surprising and exciting. (SI_AGW15)

The students also stated that the lecturer created opportunities for them to interact with online learning resources. He also provided the students with learning environments, both face-to-face and online, in which they were encouraged to exchange and present their ideas, and actively participate in the lessons.

> The teacher lets us comfortably exchange ideas and look for online resources. I think this helps us enrich our knowledge. (SI_AGW15)
> When we have questions, we send the questions to LMS. The teachers then answer us clearly and in detail whenever they have time. (SI_MGW15)

Critical thinking

Comparing students' pre-test and post-test scores

The CCTST was employed in the research. The same test was used for the pre-test and post-test. The test results show that there are statistically significant differences in total score and five individual scale scores for students' pre-tests and post-tests.

The CCTST results of the students (in both groups) show that the critical thinking skills scores of the students in the post-test is significantly higher than in the pre-test (Table 2). The mean of the total score in the post-test increases 1.8 (out of 34) ($p = 0.001$) compared with the pre-test. The five critical thinking subscores – analysis and interpretation; inference; evaluation and explanation; induction; deduction – also showed a statistically significantly improvement by the end of the semester ($p \leq 0.037$). The figures in this table show that the means of the thinking skills inference induction and deduction increase more than the means of analysis and interpretation skills and evaluation and explanation skills. The mean differences of inference, induction and deduction skills are 0.85, 0.89 and 0.91 respectively, while the mean difference of analysis and interpretation is 0.41, and evaluation and explanation 0.54.

Table 2. Combined test results

Critical thinking skills	Pre/Post	N	Mean	SD	Mean difference p (2-tailed)
Total	Post	89	13.72	3.50	Mean difference = 1.80 p (2-tailed) = 0.001 Cohen's d = 0.53 (moderate)
	Pre	90	11.92	3.31	
Analysis and interpretation	Post	89	4.09	1.28	Mean difference = 0.41 p (2-tailed) = 0.037 Cohen's d = 0.31 (modest)
	Pre	90	3.68	1.34	
Inference	Post	89	6.19	2.15	Mean difference = 0.85 p (2-tailed) = 0.009 Cohen's d =0.39 (modest)
	Pre	90	5.34	2.16	
Evaluation and explanation	Post	89	3.44	1.48	Mean difference = 0.54 p (2-tailed) = 0.017 Cohen's d = 0.36 (modest)
	Pre	90	2.90	1.50	
Induction	Post	89	6.98	2.39	Mean difference = 0.89 p (2-tailed) = 0.009 Cohen's d = 0.40 (modest)
	Pre	90	6.09	2.09	
Deduction	Post	89	6.74	2.38	Mean difference = 0.91 p (2-tailed) = 0.009 Cohen's d = 0.39 (modest)
	Pre	90	5.83	2.26	

Students' reflections on the improvement in their critical thinking skills

The questionnaire administered to the students at the end of the semester also included seven questions on critical thinking skills. The students were asked to evaluate to what extent their thinking skills had improved after this optics course in a Likert scale (not at all, a little bit, somewhat, very much and exceedingly). The critical thinking skills mentioned in these questions consist of interpretation, analysis, evaluation, interference, explanation, inductive reasoning and deductive reasoning. Cronbach's alpha reliability coefficient of the seven items measuring critical thinking skills was 0.872 – high reliability (Cohen et al., 2011).

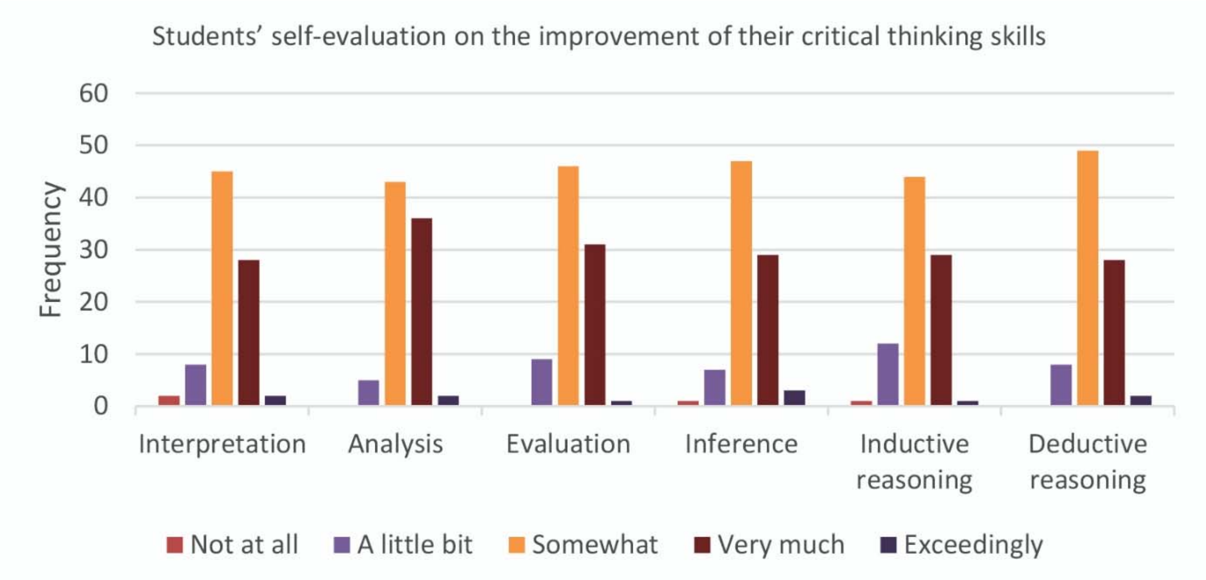

Fig. 2 Students' self-evaluation on the improvement of their critical thinking skills

The results from the students' self-evaluation on the improvement of their critical thinking skills is presented in Fig. 2. In general, most of the students who participated in the research believed that their critical thinking skills had improved to a certain extent, from a little bit to exceedingly. A majority of them said that their skills had improved somewhat or very much. Just a few students considered that their thinking skills had not been enhanced at all.

Students' learning and physics test results

To examine if the students' optics performance had improved after the implementation of the CSI model, the students' pre-test and post-test scores were compared. Data from interviews with groups of students was used to supplement data from optics test results. The optics test was an exam paper that was used in 2009. The test included 40 items and was designed by the lecturer, and the same test was used for the pre-test and post-test.

Comparing students' pre-test and post-test scores

The paired-samples t-tests were used to examine the impact of implementing the model. The use of paired-samples t-tests meant that only test scores of students who attended both the pre-test and post-test were used for the comparison in the t-test. In

Group 1, the test scores of 46 students who sat both tests were used to conduct the t-test, while in Group 2, the test scores of 32 students were used.

The results of the students' optics tests show that there are statistically significant differences between the pre-test and post-test results of the students in both groups. In general, the test scores in the post-test are higher than the scores in the pre-test. The following statistics explain in detail the differences in the test scores.

Table 3. Optics test results of Group 1

	N	Mean	SD	p (2-tailed) = 0.000
Pre-test	46	13.37	3.84	Mean difference = 15.39
Post-test	46	28.76	4.26	Cohen's d = 3.80

In Group 1, the students' optics test scores improve considerably and significantly. Table 3 and the numbers can be explained in a simple way as the average number of correct answers that a student in Group 1 performed in the optics pre-test is 13.37 out of 40 answers; this number for the optics post-test is 28.76. It means that Group 1 students' post-test scores were higher than their pre-test scores, and a student in the post-test generally supplied 15.39 more correct answers than in the pre-test. In statistical terms, if the probability value (p) is equal or less than 0.05, the result will be considered as statistically significant. The probability value '0.000' is substantially smaller than the specified probability value of 0.05. Therefore, it is concluded that there was a significant increase of 15.39 (out of 40) in the optics test scores from the pre-test (prior to the model implementation) to the post-test (after the model implementation).

Table 4. Optics test results of Group 2

	N	Mean	SD	p (2-tailed) = 0.004
Pre-test	32	12.97	2.44	Mean difference = 3.80
Post-test	32	16.77	6.45	Cohen's d = 0.85

Table 4 presents a comparison between students' optics test results pre-test and post-test (paired-sample t-test). There was a statistically significant difference between the pre-test and post-test of the students in Group 2. The mean of the pre-test is 12.97, and the mean of the post-test is 16.77. The mean difference of 3.80 shows that on average each student gains 3.80 more correct answers in the post-test, compared with the pre-test. The probability value 0.004 and Cohen's d = 0.85 reveal that the optics test scores of Group 2 increase moderately and significantly.

Comparing Group 1 and Group 2

The CSI model was implemented in both groups, with one difference in the application: Group 1 used an online learning management system for optics study, while Group 2 did not. An independent sample t-test was conducted to evaluate the difference between the two groups. The students' pre-test results show that there is no statistically significant difference between Group 1 and Group 2 (mean difference = 0.45, p = 0.515) (Table 5). In simple words, Group 1 and Group 2 are considered to be similar to each other in the optics test scores at the beginning of the semester.

Table 5. Optics pre-test results of Group 1 and Group 2

Group	N	Mean	SD	
Group 1	46	13.37	3.84	p (2-tailed) = 0.515 Mean difference = 0.45
Group 2	40	12.93	2.39	

Table 6. Optics post-test results of Group 1 and Group 2

Group	N	Mean	SD	
Group 1	53	28.74	4.28	p (2-tailed) = 0.000 Mean difference = 11.96 Cohen's d = 2.23
Group 2	35	16.77	6.45	

Table 6 describes a comparison of optics post-test results between Group 1 and Group 2. The post-test mean is 28.74 for Group 1 and 16.77 for Group 2. Mean difference is 11.96 (sig. 0.000) and effect size – Cohen's d – is 2.23 (strong effect). At the end of the semester the students in Group 1 supplied about 12 more correct answers (out of a total of 40 answers) than the students in Group 2. The post-test results of the students in Group 1 are significantly higher than the results of those in Group 2.

Interviews with students: Physics learning

The students felt that this new way of teaching helped to enhance their physics learning. It engaged them more in the learning and helped them comprehend the physics lessons faster, and they had a better understanding and became more active, dynamic and independent learners.

Findings from the students' focus group interviews showed that the students attending the optics course were deeply engaged in learning. They had read learning resources and researched optics lessons before they went to classes. They invested a lot of time studying optics at home.

The students stated that they comprehended physics lessons faster, more easily and better using this teaching method. According to the students, the applications of ICT such as computers, LCD projectors, videos and photos attract their attention and help them to comprehend optics faster and more easily. It helped them obtain in-depth understanding and enriched their optics knowledge.

The students said they became more active in learning and understood the topics more deeply.

> When the lecturer gives us tasks, we will understand specific work to do at home. We become more active in studying knowledge. When we want to stand in front of our classmates to talk, we need to understand the knowledge deeply and in detail so that we can talk. (SI_MGW14)

Moreover, the students indicated that comparing the classes at the beginning of the semester to the classes that occurred later in the semester, their classmates contributed to the lessons more actively. The learning environment was more fun. They became more dynamic and volunteered to solve assignments.

> I see the classroom is more fun and my classmates talk and contribute to lessons more actively than they did at the beginning of the semester . . . For me, my classmates become dynamic and volunteered to solve assignments. (SI_AGW15)

The students also stated that they were trained during the optics course and became more independent in their learning. The lecturer required students to research optics topics and provided them with guidance.

> For the optics course of this semester, from my observation, there is a great difference between this optics course and other courses. The lecturer lets us do research on each topic at home. Then we discuss in class. Students play roles of lecturers. (SI_MGW14)

The interviewed students believed that this way of teaching helped them develop necessary skills for learning, such as working with computers, seeking information, presenting and explaining ideas.

> I believe that when I study this course I have developed skills such as the skill of talking in public, skill of working with computers and find information online. (SI_AGW15) Learning this course I become more dynamic and learnt how to present the idea I wanted to say. (SI_MGW15)

Although the majority of students considered investing a lot of time in studying optics outside the class benefited their study, a few students perceived this is a weakness. One student said that he took many courses at the same time, so he did not have enough time to study other courses.

Technology barriers could be a challenge for utilising ICT to support learning. Some students who participated in this research did not have computers at home. They used computers in the university labs for their study. This did not help remove the technology barrier totally, but to some extent helped them to overcome the barrier.

Discussion and conclusion

The CSI model was implemented by a lecturer in a university optics course and data was collected from students and the lecturer using different methods (optics tests, CCTST, interviews and surveys) to triangulate and enrich the data.

The optics course was taught to two groups. The ICT implementation into optics teaching and learning in both groups was underpinned by the CSI model. Students of one group (Group 1) utilised more ICT applications than those in the other group

(Group 2): Group 1 students' learning was supported by a learning management system.

Student interviews showed that the interaction in the learning environment was fostered. The interaction in this research included students-students, students-teacher and students-learning resources interaction.

The optics test results show that in both groups the students' scores in the post-test were statistically significantly higher than their scores in the pre-test. In addition, in the post-test the group of students who utilised more applications of ICT to support their learning scored significantly higher than the other group. It is noted that there is no statistically significant difference in the pre-test scores of the two groups.

Results from the CCTST also showed that post-test scores of the students in both research groups were significantly higher than their pre-test scores. In the post-test, the students scored significantly higher in both the total score and the individual scores for each critical thinking skill. Students' self-evaluation results confirm these test results.

In the research context, the CSI model appears to be an effective pedagogic model. Findings showed that the model helped to improve the students' physics test scores, enhanced their critical thinking skills, and increased interaction within the learning environment.

The successful implementation of the CSI model in this study suggests some possible implications at different levels of education. At the teacher level, the current essential need for Vietnamese teachers is to acquire new understanding and skills in using ICT to support their teaching. However, little literature guides these teachers. The CSI model can be used to inform teachers how to use ICT to support teaching.

For teacher training and professional development purposes, the current study can provide teachers with insight into how to use ICT to assist students' individual and social learning. In terms of the social aspect of learning, ICT may be used as tools to promote interactions between students and teachers, students and other students, and students and learning resources.

The learning styles of Vietnamese students are strongly influenced by Confucian beliefs. It is argued that under this influence a learning style that contains cooperation and interaction is not suitable for Vietnamese students. This study shows that it is possible to develop cooperative and interactive learning in the Vietnamese context.

At the level of Vietnam's MOET, this study can provide possible guidance for the current strategy of implementing ICT into education. Although Vietnam's MOET educational reforms promote the use of ICT to support teaching with a student-centred approach, a teacher-centred approach still dominates Vietnamese classrooms. The current study shows how ICT was used to enhance student-centred learning. Training Vietnamese teachers to implement the CSI model into their teaching practice is a possible means to help the MOET achieve the goal of the educational reforms.

At the level of worldwide research, there is little searchable research in the context of Vietnam on the integration of ICT in teaching physics. The current study contributes to this literature through insights into the use of ICT to teach physics in the Vietnamese context.

As the study shows, the use of ICT informed by the CSI model can enhance interaction in the learning environment, along with students' physics performance and critical thinking skills. The model may provide useful guidance for teachers who need to integrate ICT into their teaching practice.

While the results of implementing the CSI model have been very positive, the study is limited in scale. The research was conducted in one course in a university, and while the CSI model may have worked well in this case, further work is needed to see if it is successful in other situations. The current research provides an overall picture of the effectiveness of the CSI model, but has not investigated the detailed nature of the changes to students' learning and critical thinking.

References

Brown, J. S., Collins, A., & Duguid, P. (1989). Situated cognition and the culture of learning. *Educational Researcher, 18*(1), 32–42.

Chang, J., Faikhamta, C., Na, J., & Song, J. (2018). A comparison of science classroom environments between Korea and Thailand with a focus on their cultural features. *Asia-Pacific Science Education, 4*(11), 1–22.

Cobb, P., & Bowers, J. (1999). Cognitive and situated learning perspectives in theory and practice. *Educational Researcher, 28*(2), 4–15.

Cohen, L., Manion, L., & Morrison, K. R. B. (2011). *Research methods in education* (7th ed.). New York, NY: Routledge.

Cole, M., & Wertsch, J. V. (1996). Beyond the individual-social antinomy in discussions of Piaget and Vygotsky. *Human Development, 39*(5), 250–256.

Collis, B., & Moonen, J. (2001). *Flexible learning in a digital world. Experiences and expectations.* London, England: Kogan Page.

Daniels, H. (2008). *Vygotsky and research.* New York, NY: Routledge.

Driver, R., & Oldham, V. (1986). A constructivist approach to curriculum development in science. *Studies in Science Education, 13*(1), 105–122. doi:10.1080/03057268608559933

Fosnot, C. T., & Perry, R. S. (2005). Constructivism: A psychological theory of learning. In C. T. Fosnot (Ed.), *Constructivism: Theory, perspectives, and practice* (pp. 8–38). New York, NY: Teachers College Press.

Greeno, J. G. (1997). Response: On claims that answer the wrong questions. *Educational Researcher, 26*(1), 5–17. doi:10.2307/1176867

Jonassen, D., Carr, C., & Yueh, H.-P. (1998). Computers as mindtools for engaging learners in critical thinking. *TechTrends, 43*(2), 24–32.

Harman, K., & Nguyen, T. N. B. (2010). Reforming teaching and learning in Vietnam's higher education system. In G. Harman, M. Hayden & T. N. Pham (Eds.), *Reforming higher education in Vietnam* (pp. 65-86). London, England: Springer.

Lave, J., & Wenger, E. (1991). Situated learning: *Legitimate peripheral participation.* Cambridge, England: Cambridge University Press.

Meleisea, E. (2007). *The UNESCO ICT in Education Programme.* Bangkok, Thailand: United Nations Educational, Scientific and Cultural Organization.

Muijs, D. (2004). *Doing quantitative research in education.* London, England: Sage Publications.

Ozkal, K., Tekkaya, C., Cakiroglu, J., & Sungur, S. (2009). A conceptual model of relationships among constructivist learning environment perceptions, epistemological beliefs, and learning approaches. *Learning and Individual Differences, 19*(1), 71–79.

Pea, R. D. (1997). Practices of distributed intelligence and designs for education In G. Salomon (Ed.), *Distributed cognitions: Psychological and educational considerations* (pp. 47–87). New York, NY: Cambridge University Press.

Pham, T. H. T. (2010). Implementing a student-centered learning approach at Vietnamese higher education institutions: Barriers under layers of casual layered analysis (CLA). *Journal of Futures Studies, 15*(1), 21-38.

Salomon, G., & Perkins, D. (1996). Learning in wonderland: What computers really offer education. In S. Kerr (Ed.), *Technology and the future of education.* NSSE yearbook (pp. 111–129). Chicago, IL: University of Chicago Press.

Salomon, G., & Perkins, D. N. (1998). Individual and social aspects of learning. *Review of Research in Education, 23*(1), 1–24. doi:10.3102/0091732X023001001

Thomas, D., & Brown, J. S. (2011). *A new culture of learning: Cultivating the imagination for a world of constant change.* Lexington, KY: CreateSpace.

Von Glasersfeld, E. (1989). Cognition, construction of knowledge, and teaching. *Synthese, 80*(1), 121–140.

Walliman, N. (2006). Social research methods. London, England: Sage Publications.

Watts, M., & Pope, M. (1989). Thinking about thinking, learning about learning: Constructivism in physics education. *Physics Education, 24*(6), 326–331.