

Study the Effectiveness of Technology-Enhanced Interactive Teaching Environment on Student Learning of Junior High School Biology

Kai-Ti Yang

Taichung Municipal Yu-Ying Junior High School, TAIWAN

Tzu-Hua Wang

National HsinChu University of Education, TAIWAN

Mei-Hung Chiu

National Taiwan Normal University, TAIWAN

Received 24 September 2014; accepted 27 December 2014; published 25 March 2015

This research investigates the effectiveness of integrating Interactive Whiteboard (IWB) into the junior high school biology teaching. This research adopts a quasi-experimental design and divides the participating students into the conventional ICT-integrated learning environment and IWB-integrated learning environment. Before teaching, students took the pre-test of summative assessment. The entire teaching process was recorded as a teaching video for analysis of teacher-student verbal interactions. Finally, students took the post-test of summative assessment and Constructivist Multimedia Learning Environment Survey (Maro & Fraser, 2005). The findings show that students in the IWB group have significantly better learning effectiveness. They also tend to have more positive attitudes towards their learning environment. The verbal interactions in the IWB group tend to involve less lecturing and more active participation by students.

Keywords: Interactive WhiteBoard, technology-enhanced interactive teaching, biology teaching, teacher-student verbal interaction, attitudes towards learning environment.

INTRODUCTION

In the field of biology education, cell division is generally acknowledged as a difficult topic for both teaching and learning by junior high school teachers and students (Brown, 1995; Oztap, Ozay, & Oztap, 2003). Research has also concluded that students of different

ages and stages fail to fully comprehend the process of cell division (Lewis, Leach, Wood-Robinson, 2000a, b; Lewis & Wood-Robinson, 2000; Smith, 1991). Lewis et al. (2000a, b) indicated that students' inability to completely grasp the subject results from their lack of understanding of the relationships among the basic structures of cells, chromosomes, genes, and genetic information, and that students commonly felt confused about genetics terminology. Therefore, clear illustration of the relationships among basic structures is of great assistance to students. Brown (1995) and Oztap et al. (2003) further contended that various kinds of visualization media, such as static and motion pictures of chromosomes in different stages of cell division,

Correspondence to: Tzu-Hua Wang,
Department of Education and Learning Technology,
National HsinChu University of Education, No. 521,
NanDa Rd., HsinChu City 300, TAIWAN
E-mail: tzuhuaawang@gmail.com
doi: 10.12973/eurasia.2015.1327a

State of the literature

- Cell division is acknowledged as a difficult topic of junior high school biology. Multimedia presentations are beneficial to student understanding of the dynamic nature of cell division.
- Interactive Whiteboard (IWB) enables technology-enhanced interactive and multimedia teaching. It creates two-way interaction and operation between the whiteboard and computer, forming a new interface that integrates all digital educational resources.
- Teachers made an important contribution to the classroom's learning environment or atmosphere in guiding student to learn science. Teaching activities are directly linked to students' learning accomplishments. Interaction between teachers and students plays a key role in influencing learning outcomes.

Contribution of this paper to the literature

- This research proposes an effective technology-enhanced teaching strategy to improve student learning of the topic of 'cell division' in junior high school biology.
- The teacher-student verbal interactions in IWB teaching environment tend to involve more student active participation and students in the IWB teaching environment tend to have more positive attitudes towards learning environment.
- IWB makes it easy to bring together a diverse array of learning resources, represent scientific phenomena via multi-dimensional teaching strategies and facilitate teachers in performing interactive teaching, improving student involvement in and understanding of learning materials, and improving student learning effectiveness.

could be instrumental in overcoming student difficulties in learning this topic.

Multimedia presentations including animations and videos are also beneficial to student understanding of the dynamic nature of cell division process (Brown, 1995; Oztap et al.; 2003). Amongst all Information Communication Technology (ICT), the Interactive Whiteboard (IWB) enables technology-enhanced interactive teaching and operation between whiteboards and computers, rendering IWBs the latest interface that coordinates all the digital teaching resources (Yang, Wang, & Kao, 2012). The multiple built-in educational software and dynamic arrangement of multimedia in IWBs also contribute to drawing students' attention and increase their understanding of concepts, making

teachers' instruction more versatile. Thus, IWBs appear to be a useful instructional tool in assisting students to construct a coherent conceptual framework of genetics and cell division. Moreover, the IWB trait of high interaction reduces the distance between teachers and students, as well as that amongst the students themselves (Northcote, Mildenhall, Marshall, & Swan, 2010; Smith, Higgins, Wall, & Miller, 2005).

Countries around the globe have invested greatly in this learning technology, and incorporated it into schools at different levels. IWBs have thus become one of the most visible indicators of learning technology in the educational field in the past ten years (Thomas & Jones, 2010). It is therefore necessary to research the application of IWB to teaching, for the purpose of developing appropriate teaching strategies and designs based on the advantages of IWBs for curriculum designers and instructors' reference. Consistent with the current trend of fast-developing ICTs, this research thus integrates multimedia presentations to assist students in establishing the concept of relationships among genetics basic structures. This research uses multimedia presentations such as 2D or 3D figures, animations, videos and simulations to emphasize the dynamic nature of the cell division process and elucidate the basic structures.

IWB is a new learning technology that creates a completely different learning environment from conventional classroom and an unusual pattern of interaction between teachers and students. Many empirical studies identify the positive effects of IWBs on teaching, finding that it improves learning motivation and enhances the learning effectiveness, and information competencies of both teachers and students. However, these studies large consist of small-scale research projects conducted by individual teachers at universities and middle and elementary schools in the United Kingdom, the United States, Canada, and Australia (Glover, Miller, Averis, & Door, 2005; Smith et al., 2005). Therefore, Smith et al. (2005) and Torff and Tiroff (2010) advocate continuous and official studies embodying meticulous experimental design to collect research data, in addition to self-reported data, in order to clarify IWB's influence on students' learning and distinguish the unique merits of IWB from other learning technologies. In response to this call, this research adopts a quasi-experimental design to compare student learning in the IWB-integrated and conventional ICT-integrated learning environments. Quantitative and qualitative data are collected and analyzed to investigate how the integration of IWB into a learning environment influences learning effectiveness of first-year junior high school students in learning cell division in Science and Life Technology curriculum and their attitudes towards learning environment. This research also uses

videotaping during the class to observe how IWB affects the teacher-student verbal interaction.

This research examines three questions as follows:

1. Compared to a conventional ICT-integrated learning environment, how does an IWB-integrated learning environment improve junior high school student learning effectiveness for the topic of cell division?
2. Compared to a conventional ICT-integrated learning environment, how does an IWB-integrated learning environment influence students' attitudes toward the learning environment?
3. Compared to a conventional ICT-integrated learning environment, what differences does an IWB-integrated learning environment create in verbal interactions between teachers and students?

LITERATURE REVIEW

IWB and education

In recent years, use of ICT in education has steadily grown. A form of ICT, an IWB creates two-way interaction and operation between the whiteboard and the computer, forming a new interface that integrates all digital educational resources. In addition, IWB's built-in educational software and its dynamic presentation of integrated multimedia allow teachers to be more flexible and versatile in their instruction, and helps boost student attention and improve their conceptual understandings. IWB's high interactivity also bridges the distance between teachers and students and between the students themselves (Northcote et al., 2010; Smith et al., 2005). With these advantages in mind, many countries have introduced IWBs into schools at different levels, resulting in the technology's rapid emergence over the past decade (Thomas & Jones, 2010).

The literature describes various benefits of IWBs as a teaching and learning tool, including: improvement of teaching effectiveness, multimedia/multimodal presentations, support of development and management of teaching resources, improvement of interaction level, student learning motivation and attention, and enhancement of student opportunities for participation and cooperation (BECTA, 2007; Glover et al., 2005; Smith et al., 2005). These potential advantages of IWB may be materialized as the massive educational source materials embedded in the IWB itself that are instrumental in the extension of teaching materials (Slay, Sieborger, & Hodgkinson-Williams, 2008; Smith et al., 2005). Furthermore, IWBs are able to integrate audiovisual and graphic presentations to produce versatile resources, and make instruction be more colorful and useful for everyday life (Levy, 2002). IWBs

also make courses more complete and allow students to be immersed in the courses, elevating student learning motivation and participation. In addition, the presentation of multimedia and multimodal visual nature delivered by IWBs not only facilitates student understanding of concepts, but also meets the requirements of students with different learning styles, and raises student concentration (BECTA, 2007; Glover et al., 2005; Holmes, 2009; Northcote et al., 2010; Slay et al., 2008; Smith et al., 2005; Wall, Higgins, & Smith, 2005). IWBs can also enlarge or focus on specific contents based on the teaching or different needs of students, allow notes to be taken on the panel, and record the course of interactions between teachers and students or the instruction process to be forwarded or rewound for review purposes (Slay et al., 2008; Smith et al., 2005). Unlike desktop computers in an e-Learning environment, the IWB panel generates more eye contact and interaction between teachers and students (Slay et al., 2008). The high interactivity of IWBs reduces the distance between teachers and students and between the students themselves, increasing communication and discussions in the classroom. This feature is also a key source of the benefits of integrating IWBs into teaching (Holmes, 2009; Northcote et al., 2010). Via the direct contact made by students with learning materials, resources and interactive games on the IWB panel, students are encouraged to engage in dialogue. Hence, they make more accurate decisions and monitor the learning process on their own (Smith et al., 2005). Smith et al. argued that the ability of IWBs to boost student involvement and interaction support science teaching, which requires the active participation of students. The students themselves say IWBs are useful tools in triggering and accelerating the learning process, particularly when they can operate IWBs by themselves (Slay et al., 2008; Wall et al., 2005). The visual nature of IWB, which integrates multimedia and multi-sensual presentations, reinforces learner impressions and strengthens their attention and learning motivation (Slay et al., 2008; Smith et al., 2005).

Hennessy, Deaney, Ruthven and Winterbottom (2007) also concluded that IWB provided a new window for students to express themselves in the learning environment. These expressions are not limited to speech, but also include graphics and other forms of presentation. As a result, it is easier for students to be connected to scientific knowledge and to be receptive to feedback from teachers and peers. Furthermore, the dynamic characteristics of IWBs also help students focus on analyzing, deconstructing, and explaining key concepts, as well as on discussing their ideas with other students. Gillen et al. (2008) studied integrating IWBs into science teaching in elementary schools, and found that IWBs were relatively good at consolidating presentation of various multimedia resources and ICT

functions. Murica (2008) argued that IWBs were able to link to online educational resources to acquire real life science scenarios, and in turn raised the possibility of linking active science learning and social contexts. In addition, IWB also produces a space that allows teachers and students to explore scientific ideas, ask questions and reconcile both scientific and informal concepts, creating an interactive communication pattern between teachers and students. The potential advantages mentioned above are of particular benefit to science teaching and learning (Smith et al., 2005).

Moreover, Maor and Fraser (2005) indicated that constructivist approach of teaching facilitated students' higher-order learning, which is a central goal of science education. While it is a trend for schools to increase computer usage to enhance higher-order learning, one of the methods to improve skills of higher-order thinking is for students to learn and investigate in social interaction-oriented classrooms using multimedia (Maor & Fraser, 2005). The interactive functions of IWB have the potential to offer students a constructivist learning environment with interactive context. The aforementioned literature reviews reveal IWB's characteristics which include flexibility and versatility, multimedia/multimodal presentation, and improvement of interaction between teachers and students. In addition, it provides a large panel that each and every student can watch and manage. This enables science teachers to build a shared platform and constructivist learning environment that allow multimodal and multiple presentations, which are expected to assist student learning. Thus, this research refers to Maor and Fraser's viewpoint and from the angle of constructivist multimedia learning environment, tackles learners' attitudes towards the ICT-integrated teaching environment this research organizes.

Cell division in biology and IWB teaching

Cell division is generally acknowledged as a difficult topic for both teaching and learning by teachers and students of junior high school (Brown, 1995; Oztap et al., 2003), particularly the topic of meiosis. Research identifies several difficulties, including: (1) lack of entire understanding of the physical relationship between the basic structure of genetics, and confusion about genetics terminology; (2) while cell division takes place within cells, students cannot see this process take place with their own eyes; and (3) inability to differentiate the similarities and dissimilarities of two types of cell division (Brown, 1995; Duncan, Rogat, & Yarden, 2009; Lewis et al., 2000a, b; Lewis & Wood-Robinson, 2000; Knippels, Waarlo, & Boersma, 2005; Oztap et al., 2003). Therefore, if students can be helped to construct a coherent conceptual framework, and the dynamic process of cell division can be presented using assistive

teaching devices (Brown, 1995; Lewis et al., 2000a,b; Oztap et al., 2003), students should develop a better understanding of genetics.

Cell division can be categorized into mitosis and meiosis. Students consistently fail to clearly distinguish them. Often, the purposes, processes, and products of these processes are obscure to students, and the portrayal of the relationship among these genetics-related concepts in textbooks is hard to understand. This predicament may be solved via instructional strategies that connect students to these ideas by comparing the two types of cell division, fertilization, reproductive strategies, and the related concepts (Duncan et al., 2009; Knippels et al., 2005; Lewis et al., 2000b; Stewart, Cartier, & Passmore, 2005). Because IWBs integrate multimedia/multimodal presentations, make lessons more flexible and versatile, and increase classrooms' interaction and participation level (please see the 'IWB and education' section), cell division in biology teaching can be facilitated by IWBs. Based on above, Yang and Wang (2012) proposed biology teaching strategies based on the benefits of using IWB in teaching and learning. This research designs the IWB teaching activities for the topic of cell division based on the suggestions proposed by Yang and Wang.

Student science learning and interaction between teachers and students

Studies of teacher behaviors in the classrooms in achieving instructional and managerial goals have become the focus of many researchers. In recent years, there has been an international effort in conceptualizing, evaluating, and investigating attitudes towards learning environment, an important factor in predicting student learning achievements (Fraser, 1998; She & Fisher, 2000). The ten-year cross-regional study carried out by the International Association for Evaluation of Education Achievement (IEA) (Anderson, Ryan, & Shapiro, 1989) indicated that in addition to teaching activities that are directly linked to students' learning accomplishments, students' attitudes towards science are closely connected to their perception of the learning environment (Myers III & Fouts, 1992), and affect their learning outcomes (Schibeci, 1984; Simpson & Oliver, 1985). Furthermore, teacher management of the learning environment in the classroom, along with teaching strategies and methods, are also closely related to student attitudes towards science (Myers III & Fouts, 1992; Yager, Tamir, & Huang, 1992). Wubbels and Levy (1993) observed that a positive relationship between teachers and students improved both student interest in science and academic performance. They contend that the more vigorous the interaction between teachers and students is, the more the students become involved in their academic studies. Moreover, the course of teaching

has an important influence on students learning achievement and attitude (Anderson et al., 1989). Fraser (1998) also noted that teachers made an important contribution to the classroom's learning environment or atmosphere in guiding student scientific learning. Duran and Monereo (2005) also found that different instructional approaches affected the teaching structure in classroom and the nature of interactions between teachers and students. If teachers adjust their instructional pattern to enhance teacher-student and student-student interactions, students will be encouraged to participate, improving learning results (Crawford, Chen, & Kelly, 1997). Therefore, interaction between teachers and students plays a key role in influencing learning outcomes (Anderson et al., 1989; Wubbels & Levy, 1993).

The Flanders Interaction Analysis Categories (FIAC) developed by Flanders (1970) is widely employed to analyze teacher interactions with students in the classroom (Sahlberg, 2010; Sahlberg & Boce, 2010). This research also adopts FIAC as its research basis for this purpose. The FIAC codes and analyzes observable verbal interactions between teachers and students in the classroom. Interactions are sorted into a total of 10 categories under the three major types of teacher talk, student talk and silence and confusion. In this way, FIAC documents and analyzes important events of teacher-student verbal interaction in the classroom (please see the 'Methodology' section for a more detailed introduction). The most attention-drawing feature of IWBs is their high interactivity, and the learning environment it creates is greatly different

from a learning environment integrating conventional ICT. This research thus employs FIAC to analyze and compare teacher-student verbal interactions in a conventional ICT-integrated learning environment and in a learning environment adopting IWB.

METHODOLOGY

Participants

The participants are 107 (53 male and 54 female) first-year students from four classes of a junior high school in central Taiwan. This research adopts a quasi-experimental design and assigns randomly the participating classes into two groups (Table 1): the C Group receives instruction in a conventional ICT-integrated learning environment (Microsoft PowerPoint slides with a projector and a conventional projection screen), while the IWB group receives instruction in an IWB-based learning environment.

Instruments

Interactive Whiteboard (IWB)

The IWB adopted in this research is the SmartBoard™ produced by SMART™ Technologies in Canada, which comes with analog resistive technology. The IWB is connected via a USB cable to a laptop or PC, and the laptop or PC needs to be connected to the projector so that screen of the laptop or PC will be projected onto the IWB's panel. Teachers operate the computer by touching IWB's panel, as illustrated in

Table 1. The distribution of participants

Group	Male	Female	Total
IWB group ^a	25	25	50
C group ^b	28	29	57

^aIWB group: IWB-integrated learning environment group

^bC group: Conventional ICT-integrated learning environment group

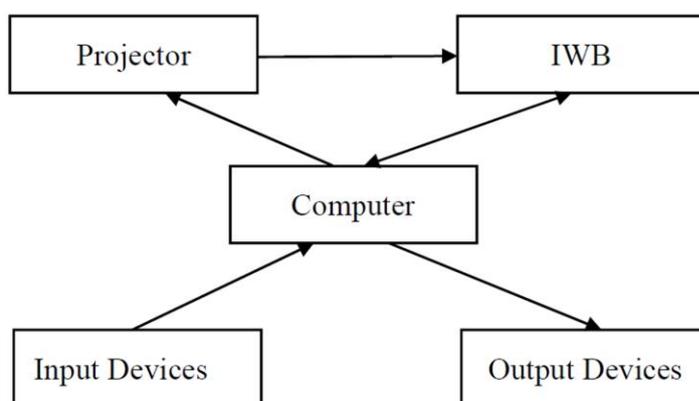


Figure 1. Interactive Whiteboard system structure and operation

Figure 1. The IWB supports text input and saves the all the drawings and notes on the panel to the connected laptop or PC.

Digital teaching materials

The teaching content adopted in this research is the topic of cell division, including the three sub-themes of ‘the chromosome and its importance,’ ‘the significance and process of mitosis,’ and ‘the significance and process of meiosis.’ The digital teaching materials for the IWB and C Groups cover the same learning concepts. The version for the C Group is constructed using Microsoft PowerPoint. This is designed for use with a projector and conventional projection screen. The version for the IWB group is primarily designed for use with an IWB, integrating multimedia/multimodal presentations. The instruction of the concept of meiosis can be taken as an example of this integration: digital

teaching materials are split into two frames on the IWB panel. Firstly, the frame on the left shows the phenomenon of meiosis, a cell dividing into four different germ cells, while the frame on the right shows a flow chart of meiosis without showing the variation of the chromosomes in the cell nucleus. Using the mask mode function, as well as question and answer guidance between teachers and students, changes in the chromosome at each stage of meiosis are presented. Through the IWB’s built-in functions of limitless copying, dragging, and moving up and down, variations in the chromosome in the process of meiosis can be broken down into steps and presented on the frame (Figure 2), followed by use of animation to display the dynamic nature of meiosis.

The teaching activities are designed to request students to work in groups and to touch the panel of the IWB to operate the digital teaching materials to answer and complete the entire procedure of meiosis.

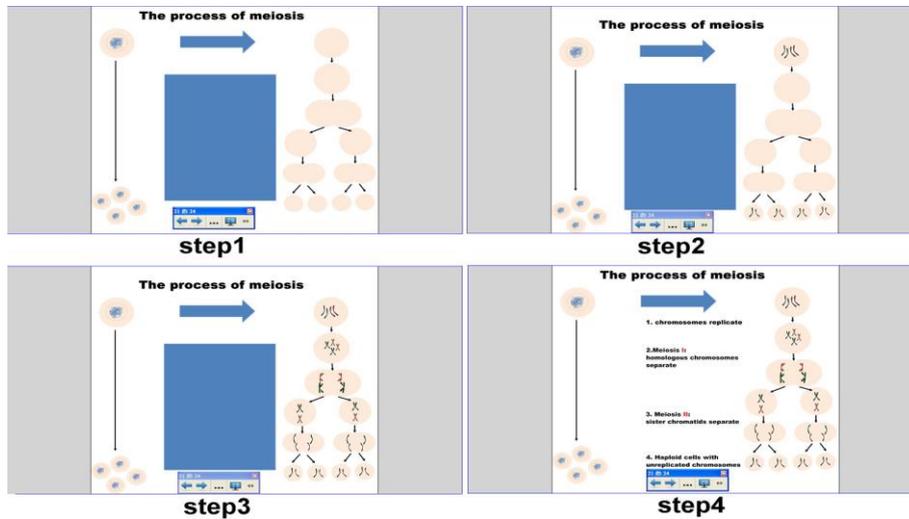


Figure 2. The four steps of teaching the concept of meiosis in IWB group. The big rectangles in this figure are the masks for the correct answers

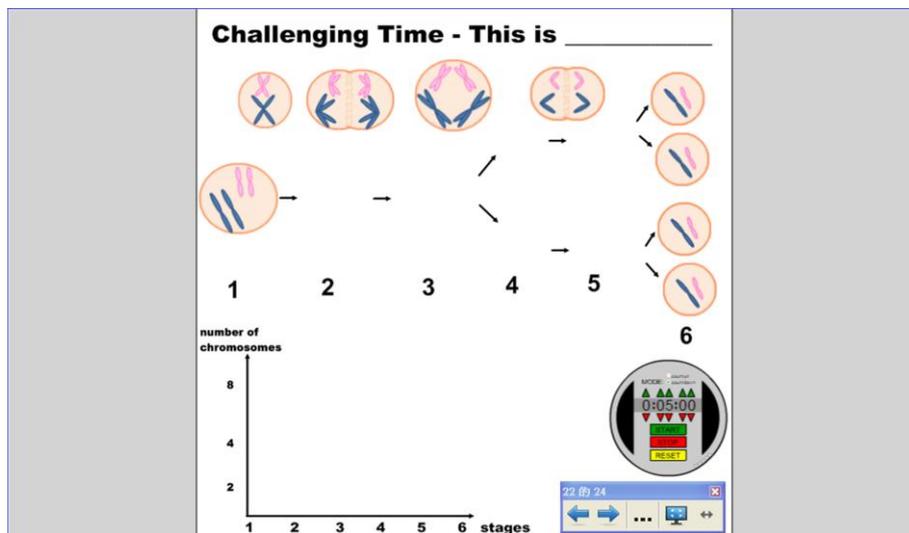


Figure 3. Screenshot of the teaching materials for the concept of meiosis in IWB group

Students can also draw on the IWB's digital teaching materials on the variations in the chromosome sets to improve their understanding of meiosis and increase their learning motivation (Figure 3). These strategies are used to enable students learn the process of meiosis using different presentations.

Summative assessment

The summative assessment is constructed based on the contents of digital teaching materials to assess student learning effectiveness. The summative assessment comprises 25 items, covering a total of 13 concepts under three sub-themes of 'the chromosome and its importance,' 'the significance and process of mitosis,' and 'the significance and importance of meiosis.' To address validity, a two-way specification table is created to ensure the questions are reasonably distributed. The items are also reviewed and revised by three experts of assessment and junior high school biology teachers. The KR20 reliability for the summative assessment is 0.790 and the average difficulty index is 0.507. In addition, the discrimination index for all items is above 0.300.

Constructivist Multimedia Learning Environment Survey (CMLES)

This research employs the Constructivist Multimedia Learning Environment Survey (CMLES) constructed by Maro and Fraser (2005) to collect attitudes towards the learning environment of students in the C and IWB groups. CMLES is used to understand student attitudes towards their learning environment when teachers apply multimedia to teaching using a constructivist instructional approach. A higher score means that students are more positive and consider their learning environment constructive. As the learning environments for the two groups are both multimedia, this research evaluates students' attitudes towards their respective learning environments with the CMLES, and attempts to understand which environment is more suitable for the constructivist learning environment. CMLES includes two components, 'the process of learning with the multimedia program' and 'the multimedia program,' and consists of six subscales. The former component mainly measures student attitudes towards the process of learning with multimedia, covering the three subscales of 'negotiation,' 'inquiry learning,' and 'reflective thinking.' The latter evaluates student reactions to interactive multimedia, including the three subscales of 'relevance,' 'complexity' and 'challenge.' The six subscales are explained below.

1. 'Negotiation' subscale: the extent to which students have opportunities to discuss their

questions and their solutions to questions.

2. 'Inquiry learning' subscale: the extent to which students are encouraged to engage in inquiry learning.
3. 'Reflective thinking' subscale: the extent to which students have opportunities to reflect on their own learning and thinking.
4. 'Relevance' subscale: the extent to which the information in the program is authentic and representative of real-life situations.
5. 'Complexity' subscale: the extent to which the program is complex and represents data in a variety of ways.
6. 'Challenge' subscale: the extent to which the multimedia program challenges and stimulates students to think.

The CMLES adopts a 5-point Likert scale with a total of 30 items. There are five items in each subscale. Cronbach's α for the CMLES is 0.950 and for subscales 1-6 above, they are 0.825, 0.885, 0.900, 0.895, 0.865, and 0.884, respectively.

Flanders Interaction Analysis Categories (FIAC)

In order to investigate the interactions between teachers and students in the C and IWB groups, this research refers to Sahlberg (2010), and Sahlberg and Boce (2010), and employs the Flanders Interaction Analysis Categories (FIAC) developed by Flanders (1970). The FIAC is used to code teacher-student verbal interactions in the learning environment of the C and IWB groups. To conform to situations in the research area and the classes conducted, instead of recording the predominant event of interaction every three seconds as a coding unit, this research records observable complete verbal interactive behaviors as a coding unit. For a thorough explanation, please refer to the 'data collection and analysis' section.

FIAC, in accordance with the concept that teachers influence students, encodes verbal interaction between teachers and students into three types and ten categories. The three types include 'teacher talk,' 'student talk' and 'silence and confusion'. 'Teacher talk' is bifurcated by 'asks questions' category into 'indirect influence' and 'direct influence'; the former includes three categories: 'accepts feeling,' 'praises or encourages,' and 'accepts or uses ideas of student,' while the latter also consists of three categories: 'lectures,' 'gives directions,' and 'criticizes or justifies authority.' 'Student Talk' includes 'student talk – response' and 'student talk – initiation' categories whereas possible silence or confusion in classrooms is classified as 'silence or confusion' category.

Research design and procedure

In order to investigate the effectiveness of integrating IWB into the teaching of the cell division topic of the Science and Technology curriculum in a junior high school, as well as its influences on student attitudes towards the learning environment and teacher-student verbal interaction, this research adopts a quasi-experimental design and allows students in the IWB group to interact directly with IWB and digital teaching materials, while students in the C Group receive conventional ICT-integrated teaching with Microsoft PowerPoint slides on a projector and projection screen. The teacher in the C Group simply displays and presents the contents of digital teaching materials, using Adobe Flash animation for illustration. Students in the C Group are not given opportunities to be in instant contact with the digital teaching materials. The teachers and the concepts covered by the digital teaching materials are identical for the two groups, with the primary difference between them being how ICT is applied to and adapted for teaching.

The first step in the research procedure is administering the pre-test of the summative assessment to the students to acquire their entry learning behavior. The two groups of students are then each given a one-week ICT-integrated teaching for a total of 5 classes. During the teaching, two cameras are installed in the front and rear of the classroom. The former covers all the students whereas the latter captures the full view of the classroom, with the focus on the teacher's instruction. After the teaching is completed, the post-test of the summative assessment and the CMLES are administered to students of both groups to understand their learning effectiveness and attitudes towards their learning environment. In addition, the teaching videos will be coded and analyzed by FIAC, to understand the differences between the C and IWB groups in teacher-student verbal interaction.

Data collection and analysis

This research collected quantitative and qualitative data. Quantitative data are derived from the summative assessment and CMLES, in order to understand student learning effectiveness and their attitudes towards the learning environment in the C and IWB groups. This research uses SPSS PC 18.0 for analysis of covariance (ANCOVA) on the scores of the pre-test and post-test of the summative assessment, and use the scores of the pre-test as the covariance, the two different ICT-integrated learning environments as the fixed factor, and the scores of the post-test as dependent variables, to investigate student learning effectiveness in the two different ICT-integrated learning environments. Moreover, to understand student attitudes towards the

two different ICT-integrated learning environments, an independent samples t-test is used on the scores of the CMLES to investigate whether a significant difference exists in student attitudes towards the IWB-integrated learning environment and the conventional ICT-integrated learning environment.

The qualitative data collected in this research are the data recorded in the teaching videos. To understand teacher-student verbal interactions in the two different ICT-integrated learning environments, the entire teaching process is recorded. This covers 5 classes of the cell division topic for a week (a class for approximately 50 minutes). The verbal interaction between the teacher and students presented in the teaching video recording data were first encoded according to the FIAC, and then the ratio of accumulated time of verbal interactions are analyzed using the Chi-square test of homogeneity. The encoding is performed by two experienced in-service teachers. The inter rater reliability is 0.863. The analysis is performed to determine whether there is a significant difference in the teacher-student verbal interaction of the two groups during the instruction.

RESULTS

Analysis of student learning effectiveness in the two different ICT-integrated learning environments

This research used independent samples t-test on the scores of the pre-test of the summative assessment to compare the entry behavior of students in the C and IWB groups. It is found that there is no significant differences in the entry behavior of students in the C and IWB groups ($t=1.456$, $p>0.05$). To understand the effectiveness of the two different ICT systems on student learning, ANCOVA was used to analyze the pre-test and post-test scores of the summative assessment. Before the analysis, the homogeneity test of the regression coefficient was performed, and the homogeneity assumption was not violated ($F=3.898$, $p>0.05$). The results of the ANCOVA are shown in Table 2.

Table 2 shows that the pre-test of the summative assessment scores have a significant impact on the post-test scores ($F=5.457$, $p<0.05$), as does the two different ICT-integrated learning environment factor ($F=7.766$, $p<0.01$). The post hoc test shows that students in the IWB group have significantly better learning effectiveness on the topic of cell division than those in the C Group.

This research performed a further analysis to understand student learning effectiveness on the three sub-themes of the topic of cell division, including 'the chromosome and its importance,' 'the meaning and process of mitosis,' and 'the meaning and process of

Table 2. ANCOVA analysis on the learning effectiveness of students in the C and IWB groups (n=107)

Sub-themes	Variables ^a	Levels	Mean (Std. Error)	F value	Post Hoc ^b
The chromosome and its importance	Pre-test ICT	C	13.757(0.755)	0.827 5.046*	IWB>C
		IWB	16.238(0.806)		
The significance and process of mitosis	Pre-test ICT	C	8.979(0.734)	0.725 3.986*	IWB>C
		IWB	11.124(0.784)		
The significance and process of meiosis	Pre-test ICT	C	18.596(1.150)	1.252 6.770*	IWB>C
		IWB	23.041(1.231)		
Total	Pre-test ICT	C	41.592(2.077)	5.457* 7.766**	IWB>C
		IWB	50.105(2.219)		

** p<0.01; *p<0.05

^a Pre-test: Scores of the pre-test of the summative assessment; ICT: ICT-integrated learning environment factor

^b Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments)

Table 3. Analysis on the scores of CMLES of students in the C and IWB groups (n=107)

CMLES	C group(n=57)		IWB group (n=50)		t value
	Mean	SD	Mean	SD	
'Negotiation' subscale	15.404	5.227	16.700	3.981	1.453
'Inquiry learning' subscale	14.281	5.713	16.480	4.156	2.295*
'Reflective thinking' subscale	15.667	5.323	18.320	4.410	2.784**
'Relevance' subscale	16.825	6.027	18.760	4.326	1.924
'Complexity' subscale	18.175	5.971	20.660	4.250	2.501*
'Challenge' subscale	16.035	6.091	19.140	4.170	3.107**
All subscales	96.386	28.318	110.060	20.422	2.889**

**p<0.01; *p<0.05

meiosis.' Table 2 shows that the scores of the pre-test of the summative assessment on the three sub-themes all have no significant effect on the scores of the post-test of the summative assessment ($p>0.05$). However, the two different ICT-integrated learning environment factor has a significant impact on the scores of the post-test of the summative assessment of the three sub-themes (chromosome and its importance: $F=5.046$, $p<0.05$; the meaning and process of mitosis: $F=3.986$, $p<0.05$; the meaning and process of meiosis: $F=6.770$, $p<0.05$). The post hoc test shows that students in the IWB group have significantly better learning effectiveness on all three sub-themes than those in the C Group.

Analysis of student attitudes towards the two different ICT-integrated learning environments

This research uses an independent samples t-test, based on the scores of the CMLES, to investigate the differences in student attitudes towards the two different ICT-integrated learning environments (Table 3). Table 3 shows that students in the IWB group have significantly more positive attitudes towards their learning environment than those in the C Group ($t=2.889$, $p<0.01$). Table 3 also shows that among the

six subscales of the CMLES, students in the IWB group have significantly better scores on the 'inquiry learning' ($t=2.295$, $p<0.05$), 'reflective thinking' ($t=2.784$, $p<0.01$), 'complexity' ($t=2.501$, $p<0.05$) and 'challenge' ($t=3.107$, $p<0.01$) subscales. However, there are no significant differences in the 'negotiation' ($t=1.453$, $p>0.05$) and 'relevance' ($t=1.924$, $p>0.05$) subscales. These results indicate that students in the IWB group, compared with those in the C Group, are more inclined to consider their learning environment a constructivist one. In addition, compared with students in the C Group, those in the IWB group tended to regard the digital teaching materials as not only easier to operate and more interesting to use, but also more challenging and stimulating for their thinking. Furthermore, students in the IWB group also considered their learning environment helpful to performing thinking and inquiry learning, and saw it as giving opportunities for reflecting on their learning and thinking. In addition, students in these two groups perceived both learning environments to be similar in offering opportunities for discussion and communication amongst peers, and presenting information relevant to daily life and pertinent and meaningful. Students also believed that the two learning environments were both representative of the complexity of real life situations.

Analysis of teacher-student verbal interaction in the two different ICT-integrated learning environments

To understand the differences in teacher-student verbal interaction in the two different ICT-integrated learning environments, this research used the FIAC to code teaching videos recording the data of the two groups, and then ratios of accumulated time of verbal interactions are analyzed by using the Chi-square test of homogeneity. The results show that there is a significant difference in the ratio of accumulated time of teacher-student verbal interactions ($\chi^2=1847.242$, $p<0.01$) (Table 4).

Table 4 shows that the top category, in terms of difference in the ratios of accumulated time of teacher-student verbal interaction between the two groups, were 'lectures.' Compared with the C Group, the ratio of accumulated time of 'lectures' fell, while that of 'asks questions' increased, which in turn raised the time of 'student talk – response' in the IWB group. Moreover, the ratios of accumulated time of teacher-student verbal interactions that raise students' participation in the class in the IWB group, such as 'accepts feelings,' 'praises or encourages,' 'accepts or uses ideas of student,' occupied 6.7% of the total instruction time, while in the C Group they occupied 5.2%. The teacher in the IWB group spent 1.4% of the total instruction time to give directions to students, primarily due to guiding students in operating the IWB, while the teacher in the C Group spent 0.2% on giving directions. Nonetheless, 1.6% of total instructional time in the IWB group was spent on the verbal interaction of 'silence or confusion,' against 1.2% in the C Group. This was mainly because the teacher needed to spend time adjusting or operating information technology equipment, including computers, the IWB, and its peripheral software and hardware facilities.

CONCLUSION AND DISCUSSION

This research adopts IWB to construct a technology-enhanced interactive teaching environment. This research also compares the effectiveness of conventional ICT-integrated learning environment and IWB-integrated learning environments on student learning effectiveness and student attitudes towards their learning environment. In the conventional ICT-integrated learning environment, the teacher designed the digital teaching materials based on the characteristics of Microsoft PowerPoint, and used a projector and projection screen to present the digital teaching materials and perform teaching activities. However, in the IWB-integrated learning environment, the teacher designed the digital teaching materials based on the characteristics of the IWB and used the IWB to perform teaching activities. Both versions of digital teaching material cover the same concepts. The findings show that students in the IWB-integrated learning environment have significantly better learning effectiveness on the topic of cell division than those in the conventional ICT-integrated learning environment. Furthermore, students have significantly more positive attitudes towards the IWB-integrated learning environment than towards the conventional ICT-integrated learning environment. Students evidently deemed the IWB-integrated learning environment to be a more constructivist learning environment than the conventional ICT-integrated learning environment. Students tended to view the IWB-integrated learning environment as providing more opportunities for them to think and to perform inquiry learning, and that the digital teaching materials presented using IWB were not only interesting and simple to operate, but also more challenging and stimulating. Moreover, the digital teaching materials designed for IWB also provided students with ample information to select from. This

Table 4. Analysis on the ratios of accumulated time of teacher-student verbal interactions

Category	IWB group Ratio(%)	C group Ratio (%)	Difference(%) (IWB group-C group)
Accepts feeling	0.4	0	0.4
Praises or encourages	0.6	0.1	0.5
Accepts or uses ideas of student	5.7	5.1	0.6
Asks questions	16.4	9.1	7.3
Lectures	49.4	67.8	-18.4
Gives directions	1.4	0.2	1.2
Criticizes or justifies authority	0	0	0
Student talk – response	23.8	15.4	8.4
Student talk – initiation	0.7	1	-0.3
Silence or confusion	1.6	1.2	0.4
Chi-Square(χ^2)	1847.242**		

** $p<0.01$

Note: Percentages obtained by dividing the accumulated time (in seconds) of each category of verbal interaction by the total time of instruction

finding echoes Maor and Fraser's (2005) standpoint that constructivist multimedia learning environment guides students for higher-order learning, and improves learners' science learning effectiveness. The findings show that, contrast to conventional ICT-integrated, IWB-integrated learning environment is more in line with features of the constructivist multimedia learning environment, and that learners demonstrate better learning effectiveness in the IWB-integrated learning environment.

Based on the analysis of teacher-student verbal interactions, it is found that there are significant differences in the ratios of accumulated time of teacher-student verbal interactions between two different ICT-integrated learning environments. The IWB-integrated learning environment tends to reduce the ratio of accumulated time of the verbal interactions of 'lectures,' and increase that of 'asks questions' and 'student talk-response' categories of verbal interaction. Those differences of teacher-student verbal interactions observable in the IWB-integrated learning environment are consistent with the features of constructivist teaching, defined by Hirumi (2002) as individuals constructing knowledge based on interactions with their exterior surroundings. This research concluded that the IWB-integrated learning environment is instrumental in reducing time spent on 'lectures' and in increasing time spent on 'asks questions' and 'student talk – response.' These findings may also explain students' better learning effectiveness in the IWB-integrated learning environment. And this finding echoes Maor and Fraser's (2005) argument. Maor and Fraser pointed out that phenomena and events that could often be observed in science classrooms emphasize memorization and lower-order learning, for example didactic approach. In order for students to experience and practice higher-order learning, implementing a constructivist-oriented pedagogy is required. From the analysis of verbal interaction between teachers and students, the findings show that compared to conventional ICT-integrated learning environment, the ratio of accumulated time of 'lecture' decreases in the IWB-integrated learning environment, while the ratio of accumulated time of verbal interaction falling into the categories of 'asks questions' and 'student talk-response' categories increases. These findings show that the interaction between teachers and students is enriched via the medium of IWB. Distinct from students in conventional ICT-integrated learning environment, those in IWB-integrated learning environment tend to consider IWB-integrated learning environment to be a constructivist one, and deem IWB digital materials not only easy to operate and fun to use, but challenging and inspiring to their thinking. The same group of students also believes IWB-integrated learning environment supports their inquiry-based learning, and permits them

to reflect on their studying and thinking. These findings reveal that the interactive attributes of IWB not only presents the learning environment in a more constructivist manner, but can also be a possible factor that contributes to learners' better learning effectiveness in the IWB-integrated learning environment.

From the aforesaid research findings, it is apparent that the primary advantages of using IWB to construct a technology-enhanced interactive teaching environment lie in improving student learning effectiveness, helping learners participate in learning and perform constructivist learning, reducing time spent on 'lectures' and increasing time spent on 'asks questions' and on 'student talk – response.' These findings can be further explained the intrinsic features of the IWB and the learning environment it creates. Hennessy et al. (2007) indicated that IWB integration provided a novel opportunity for students to operate the IWB interactively during instruction, and enabled students to be connected to science knowledge and to receive feedback from the teacher and from their peers. Holmes (2009) and Northcote et al. (2010) also observe that the high interactivity of IWBs not only reduces the distance between teachers and students and between the students themselves, but also enhances the classroom's interactions and discussions. IWB is unique in its characteristic of interactivity and multi-modal presentation, which promotes student understanding and increases their learning motivation (Gillen et al., 2007; Slay et al., 2008; Smith et al., 2005). Gillen et al. (2007), investigating the implementation of IWBs in elementary school science education, found that IWBs relatively easily integrate presentations of multiple resources and multiple ICT functions. They present an innovative possibility for promoting multidimensional teaching strategies. Moreover, integrating multimedia presentations via IWBs not only facilitates the continuity of students' learning experiences and presentation of scientific phenomena, but also encourages students to participate in learning activities and improve their understanding. Smith et al. (2005) further noted that the IWB enhancement of student participation and interaction is beneficial to science courses rich in inquiry activities and requiring student involvement. In addition, students also perceive IWBs to be effective tools that stimulate and accelerate their courses of learning, especially when they are given the opportunity to operate IWBs themselves (Slay et al., 2008; Wall et al., 2005). The visual nature of IWBs, which coordinates multimedia and multi-sensory presentations, may reinforce student impressions, and strengthen their attention and learning motivation (Slay et al., 2008; Smith et al., 2005). Thus, this research infers that IWBs make it easy to bring together a diverse array of resources and represent scientific phenomena via multi-dimensional teaching strategies, improving student

involvement in and understanding of the course materials, and improving student learning effectiveness.

As this research focuses only on the topic of cell division in the junior high school Science and Technology curriculum, this research suggests that future studies to further investigate different subjects and students of different grades. In addition to quantitative data that assess student learning effectiveness and student attitudes towards their learning environment, this research suggests enhanced collection and analysis of qualitative data, including continued video recording of classroom teaching and increased interview with students to learn the relationship between teacher-student verbal interaction and student learning experiences and student attitudes towards learning environment. Furthermore, although the learning environment integrating conventional ICT such as Microsoft PowerPoint was found to be effective in assisting students of junior high school to learn the topic of cell division, Simpson, Pollacia, Speers, Willis, and Tarver (2003) showed that while the Microsoft PowerPoint-integrated teaching may be effective in presenting and delivering instruction, students were not satisfied with such instruction without any additional teaching activities to maintain student learning motivation. In other words, teachers need to design more teaching activities to attain the expected effectiveness with Microsoft PowerPoint-integrated teaching. Simpson et al.'s views can also be leveraged to explain the findings of this research. In contrast to the IWB-integrated learning environment, the conventional ICT-integrated learning environment, primarily using Microsoft PowerPoint for instruction, shows that lecturing by teachers dominated teacher-student verbal interaction, students often passively accepted the knowledge teachers passed on, the proportion of accumulated time of students' response to the teacher was lower, and students have less positive attitudes towards their learning environment, as they considered such learning environment as providing fewer opportunities for them to perform inquiry learning and thinking, and was less challenging. As both classes employing IWB and Microsoft PowerPoint use the projector to project digital teaching materials during instruction, without properly exploiting the unique interactive functions of the IWB, it is easy for the IWB-integrated teaching to look similar to the Microsoft PowerPoint-integrated teaching, and fail to demonstrate the effectiveness of IWB on student learning. This research hence recommends that teachers employing IWB thoroughly comprehend and apply IWB's distinctive interactive features to teaching activities to ensure the effectiveness of IWB-integrated learning environments. Future researchers are also advised to further explore how to improve the quality of IWB-integrated teaching through teacher training.

Authors' Note

All the trademarks and product names referred to in this paper are the property of their respective owners. In addition, all the figures adopted in this paper are the property of their respective owners. Some objects used in the figures are adopted from the NoteBook™ software, provided by SMART Technologies™. For more information about the NoteBook™ software, you can visit <http://smarttech.com/>

Acknowledgement

The authors deeply appreciate the Ministry of Science and Technology in Taiwan (R.O.C.) for the financial support and encouragement under Grant No. 99-2511-S-134-002-MY3, 99-2511-S-003-024-MY3, 102-2511-S-134-002-MY3, 102-2511-S-003-006-MY3. The authors are grateful for the insightful comments from the Editor and referees.

REFERENCES

- Anderson, L., Ryan, D. W. L., & Shapiro, B. J. (1989). *The IEA Classroom Environment study*. Oxford: Pergamon Press.
- British Educational Communications and Technology (2007). *Harnessing Technology schools survey 2007*. Retrieved August 1, 2014, from http://dera.ioe.ac.uk/1554/1/becta_2007_htssfindings_report.pdf
- Brown, C. R. (1995). *The Effective Teaching of Biology*. New York, USA: Longman publishing.
- Crawford, T., Chen, C. & Kelly, G. J.(1997). Creating authentic opportunities for presenting science: The influence of audience on student talk. *The Journal of Classroom Interaction*, 32, 1-13.
- Duncan, R. G., Rogat, A. D., & Yarden, A.(2009). A learning progression for deepening students' understanding of modern genetics across the 5th-10th grades. *Journal of Research in Science Teaching*, 46(6), 655-674.
- Duran, D., & Monereo, C. (2005). Styles and sequences of cooperative interaction in fixed and reciprocal peer tutoring. *Learning & Instruction*, 15, 179-199.
- Flanders, N. A. (1970). *Analyzing teaching behavior*. Reading, Massachusetts: Addison-Wesley Publishing Company.
- Fraser, B. J. (1998). Science learning environment: Assessment, effects, and determinants. In B. J. Fraser and K. G. Tobin (Eds.), *The International Handbook of Science Education*. Dordrecht, The Netherlands: Kluwer Academic Publishers.
- Glover, D., Miller, D., Averis, D., & Door, V. (2005). The interactive whiteboard: A literature survey. *Technology, Pedagogy and Education*, 14(2), 155-170.
- Gillen, J., Littleton, K., Twiner, A., Staarman, J. K., & Mercer, N. (2008). Using the interactive whiteboard to resource continuity and support multimodal teaching in a primary science classroom. *Journal of Computer Assisted Learning*, 24(4), 348-358.
- Hennessy, S., Deaney, R. , Ruthven, K., & Winterbottom, M. (2007). Pedagogical strategies for using the interactive

- whiteboard to foster learner participation in school science. *Learning, Media and Technology*, 32(3), 283-301.
- Hirumi, A. (2002). Student-centred, technology-rich learning environments (SCen-TRLE): Operationalizing constructivist approaches to teaching and learning. *Journal of Technology and Teacher Education*, 10, 497-537.
- Holmes, K. (2009). Planning to teach with digital tools: Introducing the interactive whiteboard to pre-service secondary mathematics teachers. *Australasian Journal of Educational Technology*, 25(3), 351-365.
- Knippels, M. P. J., Waarlo, A. J., & Boersma, K. T. (2005). Design criteria for learning and teaching genetics. *Journal of Biological Education*, 39(3), 108-112.
- Levy, P. (2002). *Interactive whiteboards in learning and teaching in two Sheffield schools: A developmental study*. Retrieved January 1, 2012, from <http://dis.shef.ac.uk/eirg/projects/wboards.htm>
- Lewis, J., & Wood-Robinson, C. (2000). Genes, chromosomes, cell division and inheritance – Do students see any relationship? *International Journal of Science Education*, 22, 177-197.
- Lewis, J., Leach, J., & Wood-Robinson, C. (2000a). What's in a cell? – young people's understanding of the genetic relationship between cells, within an individual. *International Journal of Biological Education*, 34, 129-132.
- Lewis, J., Leach, J., & Wood-Robinson, C. (2000b). Chromosomes: The missing link – Young people's understanding of mitosis, meiosis, and fertilisation. *International Journal of Biological Education*, 34, 189-199.
- Maor, D., & Fraser, B. J. (2005). An online questionnaire for evaluating students' and teachers' perceptions of constructivist multimedia learning environments. *Research in Science Education*, 35, 221-244.
- Murcia, K. (2008). Teaching for scientific literacy with an interactive whiteboard. *Teaching Science*, 54(4), 17-21.
- Myers III, R. E., & Fouts, J. T. (1992). A cluster analysis of high school classroom environments and attitude toward science. *Journal of Research in Science Teaching*, 29, 929-937.
- Northcote, M., Mildenhall, P., Marshall, L., & Swan, P. (2010). Interactive whiteboards: Interactive or just whiteboards? *Australasian Journal of Educational Technology*, 26(4), 494-510.
- Oztap, H., Ozay, E., & Oztap, F. (2003). Teaching cell division to secondary school students: An investigation of difficulties experienced by Turkish teachers. *International Journal of Biological Education*, 38, 13-15.
- Sahlberg, P. (2010). Hope of cooperative learning: Intentional talk in Albanian secondary school classrooms. *Intercultural Education*, 21(3), 205-218.
- Sahlberg, P., & Boce, E. (2010). Are teachers teaching for a knowledge society? *Teachers and Teaching: Theory and Practice*, 16(1), 31-48.
- Schibeci, R. A. (1984). Attitudes to science: An update. *Studies in Science Education*, 11, 26-59.
- She, H-C., & Fisher, D. (2000). The development of a questionnaire to describe science teacher communication behavior in Taiwan and Australia. *Science Education*, 84(6), 706-726.
- Simpson, C. L., Pollacia, L., Speers, J., Willis, T. H., & Tarver, R. (2003). An analysis of certain factors related to the use of powerpoint. *Communications of the International Information Management Association*, 3(2), 73-83.
- Simpson, R. D., & Oliver, J. S. (1985). Attitudes toward science and achievement motivation profiles of male and female science students in grade six through ten. *Science Education*, 69, 511-526.
- Slay, H., Sieborger, I., & Hodgkinson-Williams, C. (2008). Interactive whiteboard: Real beauty or just lipstick? *Computers & Education*, 51(3), 1321-1341.
- Smith, M. U. (1991). Teaching cell division: Students' difficulties and teaching recommendations. *Journal of College Science Teaching*, 21, 28-33.
- Smith, H. J., Higgins, S., Wall, K., & Miller, J. (2005). Interactive whiteboards: Boon or bandwagon? A critical review of the literature. *Journal of Computer Assisted Learning*, 21(2), 91-101.
- Stewart, J., Cartier, J. L., & Passmore, C. M. (2005). Developing understanding through model-based inquiry. In M. S. Donovan & J. D. Bransford (Eds.), *How Students Learn: Science in the Classroom*. Washington, DC: The National Academies Press.
- Thomas, M., & Jones, A. (2010). Interactive whiteboards: An Australasian perspective. *Australasian Journal of Educational Technology*, 26(4), iii-vi.
- Torff, B., & Tirotta, R. (2010). Interactive whiteboards produce small gains in elementary students' self-reported motivation in mathematics. *Computers & Education*, 54(2), 379-383.
- Wall, K., Higgins, S., & Smith, H. (2005). 'The visual helps me understand the complicated things': Pupil views of teaching and learning with interactive whiteboards. *British Journal of Educational Technology*, 36(5), 851-867.
- Wubbels, T. & Levy, J. (1993). *Do you know what you look like: interpersonal relationships in education*. London: Falmer.
- Yager, R. E., Tamir, P., & Huang, D-S. (1992). An STS approach to human Biology instruction affects achievement & attitudes of elementary Science majors. *The American Biology Teacher*, 54(6), 349-355.
- Yang, K. T., Wang, T. H., & Kao, Y. C. (2012). How an interactive whiteboard impacts a traditional classroom. *Education as Change*, 16(2), 313-332.
- Yang, K.T., & Wang, T. H. (2012). Interactive WhiteBoard: Effective interactive teaching strategy designs for Biology teaching. In Anderson Silva, Elvis Pontes, Adilson Guelfi and Sergio Takeo Kofuji (Eds.), *E-Learning - Engineering, On-Job Training and Interactive Teaching* (pp. 139-156). Croatia: InTech.

