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Evaluating the Instructional Architecture of Web-Based Learning Tools (WBLTs): Direct Instruction vs. Constructivism Revisited

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Web-based learning tools (WBLTs), also known as learning objects, have been evaluated with a wide range of metrics, but rarely with respect to pedagogical design. The current study evaluated the impact of instructional architecture (direct instruction vs. constructive-based) on middle (n=333) and secondary (n=389) school student attitudes (learning, design, and engagement) and learning performance (remembering, understanding, and application tasks) with respect to WBLTs. Students rated WBLTs with a direct instruction architecture significantly higher than WBLTs with a constructive-based architecture in the areas of learning effectiveness, design, and engagement. Students also commented that a direct instruction format had better organization and visual supports, higher quality graphics and animations, and superior help features. Students performed significantly better in the understanding and application knowledge categories when a direct instruction format was employed. No significant differences were observed between direct instruction and constructive-based architectures with respect to the remembering knowledge category. It is speculated that a direct-instruction design may be better suited to younger students who are learning basic level concepts, although more research is needed to explore higher level knowledge areas.

Overview

Web-Based Learning Tools (WBLTs), also referred to in the literature as learning objects, are defined in this study as "interactive online tools that support learning specific concepts by enhancing, amplifying, and/or guiding the cognitive processes of learners" (Kay, 2009; Kay & Knaack, 2008b, 2009b). While efforts have been made to examine the impact of WBLT design (e.g., Cochrane, 2005; Haughey & Muirhead, 2005; Kay & Knaack, 2008b; Krauss & Ally, 2005; Nesbit & Belfer, 2004), instructional architecture or the underlying pedagogy used by WBLTs has not been systematically examined, particularly in middle and secondary school environments. Two prominent WBLT architectures are based on direct-instruction and constructivism (e.g. Clark, 2008; Kay & Knaack. 2008b, 2009b). Direct instruction WBLTs typically involve the presentation of a specific concept followed by a question and answer segment used to assess understanding. Constructive WBLTs are usually problem driven and require the user to explore and test "what-if" scenarios. The purpose of this study was to compare direct instruction vs. constructive WBLTs according to the attitudes and learning performance of middle and secondary school students studying mathematics or science.

Evaluating WBLTs

Considerable research conducted in the past 10 years suggests that WBLTs are effective learning aids for teachers and students (e.g., Haughey, & Muirhead, 2005; Kay, 2009; Kay & Knaack, 2008a, 2009a; Nurmi, S., & Jaakkola, 2006a). However, not all WBLTs have a positive impact on learning (e.g., Kay & Knaack, 2007a, 2007b; McCormick & Li, 2005; Nurmi & Jaakola, 2006b). Kay & Knaack (2008b) argue that it is critical to understand and evaluate WBLTs in detail in order to understand the parameters that contribute to effective learning.

The majority of WBLT evaluation has been informal (e.g., Bradley & Boyle, 2004; Clarke & Bowe, 2006a, 2006b; Concannon et al., 2005; Fournier-Viger et al., 2006; Kenny, Andrews, Vignola, Schilz, & Covert, 1999; Lopez-Morteo & Lopez, 2007; MacDonald et al., 2005), however, several researchers have articulated and developed comprehensive assessment models (Cochrane, 2005; Haughey & Muirhead, 2005; Kay & Knaack, 2005; Krauss & Ally, 2005; Nesbit & Belfer, 2004). Unfortunately, the reliability, validity, and impact of these models have not been rigorously tested (Kay & Knaack, 2008b). Kay & Knaack (2008b) developed and examined the Learning Objects Evaluation Metric and reported good internal reliability and validity estimates. This metric targeted four key areas of WBLTs including interactivity, design, engagement, and usability. Kay & Knaack (2008b), though, did not examine the instructional architecture or the pedagogy used in particular WBLTs. Kirschner, Sweller, & Clark (2006) argue that understanding the pedagogical approach or level of instructional guidance is critical for evaluating successful learning.

Pedagogy and WBLTs

Most research on pedagogy and the use of WBLTs has focused on choices made by instructors when using WBLTs in their classrooms. Key areas of focus have included preparation time (Kay, Knaack & Muirhead, 2009), coaching or facilitation (Liu & Bera, 2005), establishing context (Schoner, Buzza, Harrigan, & Strampel, 2006), purpose of using WBLT (Kay et al., 2009), asking students to evaluate their own actions while learning (van Marrienboer & Ayres, 2005), and providing some sort of instructional guide or scaffolding (Brush & Saye, 2001; Concannon et al.,, 2005; Kay et al., 2009; Lim, Lee & Richards, 2006; Mason, Pegler, &Weller, 2005; Mayer, 2004).

Systematic investigation of the instructional architecture of WBLTs is noticeably absent. Because a majority of articles, particularly in the domain of higher education, view WBLTs as stand-alone tools to be used independently by students (e.g., Kong & Kwok, 2005; Oliver & McLoughlin, 1999; Poldoja, Leinonen, Valjataga, Ellonen, & Priha, 2006), the pedagogy underlying the design is crucial for success. Instructional architecture may be even more important for middle and secondary school students who do not perform as well higher education students when asked to work on WBLTs with minimal guidance and interaction from an instructor (Kay & Knaack, 2007a; Nurmi & Jaakkola, 2006a).

Direct Instruction vs. Constructivism

Two principle types of WBLTs have emerged in education: direction instruction and constructive-based (e.g., Haughey, & Muirhead, 2005; Kay, 2009; Kay & Knaack, 2008b; Nurmi, S., & Jaakkola, 2006a). Direct instruction WBLTs typically present or demonstrate a concept, then ask a series of questions to test mastery. Constructive-based WBLTs allow students to investigate and test “what-if” scenarios in a more open-ended environment in order to build knowledge. Considerable debate exists about which of these two instructional designs works best (Kirschner et al., 2006). Some studies suggest direct instruction is a more effective approach to teaching (e.g., Cronbach & Snow, 1977; Mayer, 2004; Sweller, 2003). However, the majority of research indicates that learning is best supported when students are given the essential tools and required to construct understanding and meaning themselves (e.g., Bruner, 1986; Papert, 1980; Steffe & Gale, 1995; Vannatta & Beyerbach, 2000; Vygotsky, 1978). The constructivist approach has been widely embraced by many educational communities, however Kirschner et al. (2006) provide substantial evidence that direct instruction is significantly more effective, especially when students have a primitive understanding concepts to be learned. To date, it is unclear whether middle and/or secondary students learn best with direct instruction or constructive-based WBLTs.

Purpose of Study

The purpose of the current study was to investigate and compare direct instruction vs. constructive-based WBLTs. The two main research questions were:

1. Are there significant differences in students attitudes toward direct instruction vs. constructive-based WBLTs?
2. Are there significant differences in students performance when using direct instruction vs. constructive-based WBLTs?

METHOD

Overview

The following protocol was followed to maximize the quality of data collected:

1. reliable, valid, and research-based survey tools were employed to collect data on student attitudes toward WBLTs;
2. WBLTs were pre-selected for teachers based on the Kay & Knaack’s (2008b) multi-component approach for evaluating WBLTs;

3. pre-designed lesson plans were created by trained teachers and derived from previous research looking at effective strategies for using WBLTs (Kay et al., 2009; and
4. an enhanced measure of student performance was developed for each WBLT based on the revised Bloom's taxonomy (Anderson & Krathwhol, 2001).

Sample

Students. The student sample consisted of 722 middle (n=333) and secondary (n=389) school students (339 males, 382 females) who were 11 to 17 years of age (M = 13.4, SD = 0.99). Students were enrolled in grades seven (n=191), eight (n=142), nine, (n=346), and ten (n=43). Subject areas covered by the WBLTs included mathematics (46%, n=333) and science (54%, n=389). Most students reported average grades of 60 to 69 percent (n=117, 16%), 70 to 79 percent (n=266, 37%), or 80-89 percent (n=207, 29%). Just under 60% (n=410) agreed or strongly agreed they were good at the subject in which the WBLT was used. Only 45% (n=322) agreed or strongly agreed that they liked the subject taught with the WBLT. Three quarters of the students (n=555) agreed or strongly agreed that that they were good at working with computers. The student population data was gathered from 33 different middle and secondary school classrooms located within two suburban regions with over 500,000 people in each area.

Teachers. Eighteen middle school and 15 secondary school teachers participated in this study (8 males, 25 females). Specific grades taught were seven (n=9), eight (n=9), nine (n=12) and 10 (n=3). Teaching experience ranged from 0.5 to 23 years with a mean of 6.3 (SD = 6.4). Thirty out of 33 teachers (91%) agreed or strongly agreed that they were comfortable with using computers at school. Frequency of typical classroom computer use varied widely with the majority of teachers using computers once each term (n=7), once a month (n=10) or every two weeks (n=5). The average number of working days it took to book a computer lab to use the WBLTs ranged from 0 to 34 with a mean of 8.3 (SD = 8.1).

WBLTs and lesson plans. Four teachers (not involved in the study) participated in a two-day workshop on how to (a) select high-quality WBLTs for the classroom and (b) develop effective lesson plans. The criteria for choosing WBLTs was derived from Kay & Knaack's (2008b) multi-component model for evaluating WBLTs. The lesson plan design was based on the results of Kay et al.'s (2009) research on successful strategies for using WBLTs. Key components of a typical lesson plan in this study included a (a) guiding set of questions, (b) structured, well-organized plan for using the WBLTs, and (c) time to consolidate concepts learned. A standard lesson was about 70 minutes long and consisted of an introduction (10 min.), guiding questions and activities involving the use of an WBLT (50 minutes), and consolidation (10 min).

A database of 122 lesson plans and WBLTs was created over a period of two months (78 for mathematics and 44 for science). Twenty-four WBLT lessons were selected from this database by teachers in this study. See Appendix A (Kay, 2011a) for links to all WBLTs, lesson plans, and pre-post tests used by mathematics teachers.

Procedure

Educational coordinators from two boards of education informed teachers of the opportunity to participate in the current research study. Teachers who volunteered, participated in a full day of training on how to use WBLTs and the pre-designed lesson plans. After the workshop, teachers who still wanted to be involved in the study were asked to use at least one WBLT in their classroom within the following three months. Email support was available for the duration of the study. All students in a given teacher's class participated in the WBLT lesson chosen by the teacher, however, survey and pre-post test data was only collected from those students with signed parental permission forms.

Independent Variable

The independent variable in this study was instructional architecture. Each WBLT was categorized according to the underlying pedagogical strategy used in the design: direct instruction or constructive-based. A "direct instruction" instructional architecture presented information in a relatively passive manner, then tested students with a series of online questions. A "constructive-based" instructional WBLT architecture was tool-based and required students to explore and test "what-if" scenarios in order to construct meaning and understanding (Clark, 2008).

Eighteen WBLTs employed a "direct instruction" instructional architecture and were used by a total of 374 students. Knowledge areas targeted by direct instruction WBLTs included remembering (83%), understanding (33%), application (55%) and analysis (16%). Fourteen WBLTs followed a "constructive-based" instructional architecture were used by a total of 348 students. Knowledge areas targeted by constructive-based WBLTs included remembering (50%), understanding (21%), application (100%) and evaluation (7%).

Dependent Variables

Student attitudes toward WBLTs. When the WBLT lesson was finished, students with signed permission forms filled in the *WBLT Evaluation Scale for Students* to assess their attitudes about how much they had learned (learning construct), the design of the WBLT (design construct), and how engaged they were while using the WBLT (engagement construct). These constructs were based on a comprehensive review of the literature on evaluating WBLTs (Kay & Knaack, 2008a, 2009b). The scale showed good reliability, face validity, construct validity, convergent validity, and predictive validity (Kay & Knaack, 2009b). Internal-reliability scale estimates in the current study were 0.90 (perceived learning), 0.85 (design of WBLT), and 0.91 (engagement). See Appendix B (Kay, 2011b) for a copy of the scale used.

Students were also asked to answer two open-ended questions regarding what they liked and disliked about the WBLT they used (Appendix B – questions 10 and 11 in Kay, 2011b). These qualitative items were organized according to the three main constructs identified in the *WBLT Evaluation Scale for Students* (i.e., learning, design, and engagement) and analysed using the coding scheme provided in Appendix C (Kay, 2011c). This coding scheme was used to categorize 863 student comments. Each comment was then rated on a five-point Likert scale (-2 = very negative, -1 = negative, 0 = neutral, 1 = positive, 2 = very positive). Two raters assessed all comments made by students and achieved inter-rater reliability of 99% on the categories and 100% on the ratings.

Student performance. Students completed pre- and post-tests based on the content of the specific WBLT they used in class. These tests were included with all pre-designed lesson plans to match the learning goals of the WBLT (see Appendix A in Kay, 2011a). The percent difference between pre- and post-test scores was used to assess changes in student performance on five possible knowledge categories from the revised Bloom's Taxonomy (Anderson & Krathwhol, 2001) and included remembering, understanding, application, analysis, and evaluation. The number of knowledge categories assessed in any one class varied according the learning goals of each WBLT used.

Data Analysis

To compare direct instruction vs. constructive-based instructional architectures with respect to student attitudes toward WBLTs, a MANOVA was used because three constructs were being assessed simultaneously. A MANOVA was also considered to examine the impact of instructional architecture on learning performance, however, not all knowledge categories were assessed for every WBLT. In other words, each WBLT had a distinct set of learning goals that rarely encompassed more than two of the five Bloom's knowledge areas, therefore the MANOVA could not be run. It was determined that an ANCOVA was a better statistical test to use and would help minimize the impact of extraneous variables including gender, average grade, subject comfort level, and computer comfort level.

RESULTS

Student Attitudes Toward WBLTs and Instructional Architecture

Survey data. Middle and secondary school students had significantly more positive attitudes towards WBLTs when the instructional architecture followed a direct instruction format. Attitudes toward WBLT learning features ($p < .001$), design ($p < .001$), and engagement ($p < .001$) were significantly higher than a constructive-based format with effect sizes ranging from low to moderate based on Cohen's D (Cohen, 1988, 1992) (Table 1).

Table 1
MANOVA for Student Attitudes toward WBLTs as a Function of Instructional Architecture

Question Type	Direct Instruction (n= 359)	Constructive Learning (n=342)	F	Effect Size
Student Attitude Toward:				
Learning	26.3 (5.9)	24.7 (5.9)	11.4 *	0.27
Design	22.5 (3.9)	20.6 (3.9)	41.2 *	0.49
Engagement	20.4 (5.0)	19.1 (5.0)	11.7 *	0.26

* $p < .001$

Student comments- learning. With respect to the learning category, student feedback about overall learning was positive and similar for direct instruction and constructive-based learning architectures (Table 2). Student comments about visual supports provided by a WBLT to assist learning were more frequent and positive for direct instruction than constructive-based formats (Table 2). Finally, with respect to learning challenge, both instructional architectures were viewed negatively by students, however, negative remarks about the constructive-based WBLTs appeared to be more intense based on the mean rating scores (Table 2). See table 3 for sample comments of each learning category and instructional architecture.

Table 2

Student Comments as a Function of Instructional Architecture

		Direction Instruction				Constructive			
Category		Mean	(S.D)	n	Total Effect	Mean	(S.D)	n	Total Effect
Learning									
	Visual Supports	1.10	(0.59)	49	54.0	0.94	(0.73)	31	29.0
	Overall Learning	0.39	(1.19)	61	24.0	0.50	(1.17)	44	22.0
	Challenge	-0.71	(1.04)	38	-27.0	-1.00	(0.93)	43	-43.0
Design									
	Easy	1.09	(0.29)	33	36.0	0.44	(1.08)	36	16.0
	Interactive	0.42	(1.02)	19	8.0	0.50	(1.00)	28	14.0
	Graphics	0.42	(1.10)	48	20.0	0.00	(1.17)	29	0.0
	Animation	0.52	(1.09)	29	15.0	0.56	(0.88)	9	5
	Theme	-0.20	(1.23)	25	-5.0	0.29	(1.20)	14	4.0
	Organization	0.00	(1.23)	21	0.0	-1.14	(0.83)	22	-25.0
	Help	-0.55	(1.29)	11	-6.0	-0.95	-0.95	21	-20.0
Engagement									
	Like Technology	0.69	(0.87)	42	29.0	0.54	(0.90)	37	20.0
	Compare	0.92	(0.69)	36	33.0	0.59	(0.91)	22	13.0
	Engaging	0.20	(1.28)	55	11.0	0.18	(1.26)	57	10.0

Student comments - design. Students reported that WBLTs with a direct instruction learning architecture were easier to use, had better graphics and animations, were better organized, and had clearer help features than WBLTs with a constructive-based instructional architecture (Table 2). Students perceived that direct instruction and constructive architectures were similar with respect to interactivity and theme (Table 2). See table 4 for sample comments about WBLT design categories as a function of instructional architecture.

Table 3
Sample Student Comments about WBLT Learning as a Function of Instructional Architecture

Category	Direct Instruction	Constructive
Overall Learning	"I liked the learning object because it made it easier to learn new concepts" "Good review for previously learned concepts"	"It helped me with drawing nets and learning volume and surface area" "I liked the ball experiment that helped me learn about viscosity"
Visual Supports	"There were diagrams to make the subject clearer to learn." "I liked that it was 3D and gave a better visual of the cell." "It helped you visualize how the object was working"	"I liked how there were diagrams that moved and helped you understand the stages better." "I liked using the zero tool (graphics), it made things easier!"
Challenge Level	"The words were very complicated, and it wasn't very in depth." "It was sometimes difficult to follow."	"The learning object was very hard to follow and understand. It wasn't very organized and was hard to use." "[It was] sometimes hard to understand. Some of the stuff we needed wasn't even on the site."

Student comments - engagement. Students using direct instruction vs. constructive instructional architectures did not differ in their desire to use technology in class or their perceptions about how engaging WBLTs were (Table 2). However, students using WBLTs with a direct instruction format were more positive about WBLTs when comparing them to a regular class format. See table 5 for sample comments about WBLT engagement categories as a function of instructional architecture.

Table 4
Sample Student Comments about WBLT Design as a Function of Instructional Architecture

Category	Direct Instruction	Constructive
Easy to Use	"It was easy to follow" "It was easy to use"	"It was complicated to use" "It does not explain in full details what is actually going on."
Interactive	"I liked how you can guess where the cell parts are." "I liked how it had us interact with what we were learning."	"I liked how it was more interactive." "I got to make my own circuit and see by making it myself."
Graphics	"It was colourful." "I liked the graphics and diagrams used."	"It was not eye catching" "I would make the graphics better."
Animation	"The animations were very helpful." "I liked how it had different colours and animations to keep the attention of the viewer"	" I liked the animations part"
Theme	"I liked the game we played "It seemed a little too childish."	"[I liked playing] the integer game." "I did not like that the batteries did not catch fire"
Organization	"It was well organized." "Some things in the object were a little unorganized and could have been presented a little more neatly.	"I found it very hard to use and the instructions were not easy to follow." "I didn't enjoy the confusion at the start up, too many links from the start off page. "
Help Features	"I found the instructions hard to completely understand." "The instructions weren't as clear as they could have been."	"[The] directions were a little difficult to follow." "[The] instructions were a bit hard."

Learning Performance and Instructional Architecture

A total of five Bloom's knowledge categories were evaluated: remembering, understanding, application, analysis, and evaluation. No significant differences were observed in the remembering knowledge category between direct instruction and constructive-based instructional architectures. Students performed significantly better in the understanding (21% difference, $p < .001$) and application (15 % difference, $p < .001$) knowledge categories when a direct instruction as opposed to a constructive-based instructional architecture was used. The effect size of these differences, based on Cohen's D, are considered large (Cohen, 1988, 1992). Differences between instructional architectures in analysis and evaluation categories could not be assessed due to insufficient data. Finally, total performance scores were significantly higher (16% difference, p <.001) for WBLTs that used an instructional architecture based on direct instruction. The effect size of this difference, based on Cohen's D, is considered large (Cohen, 1998, 1992). (Table 3)

Table 5

Sample Student Comments about WBLT Engagement as a Function of Instructional Architecture

Category	Direct Instruction	Constructive
Like Technology	"I liked the fact that we got to go on the computers during class." "I liked working on the computer."	"[I liked that] you get to use computers in class." "I liked that it was computer based."
Compare	"I liked how we got to use computers not boring textbooks." "It was more fun to use the computers rather than sit in class."	"I would rather do the work on the computer than on a sheet of paper." "It was very easy and boring. I felt that I could have learned this in a book."
Engaging	"I liked learning this way because it was fun." "It was not very entertaining."	"I liked we actually had to do something that was kind of fun, but just a little bit." "It was slightly boring and very monotonous."

DISCUSSION

The purpose of this study was to compare two instructional architectures used in WBLTs - direct instruction and constructive-based. Student attitudes and learning performance were used to assess potential differences. Each of these parameters will be discussed in turn.

Table 6
ANCOVA for Student Performance (Pre vs. Post-Test) as a Function of Instructional Architecture

Question Type	n	Direct Instruction (% change)	n	Constructive Learning (% change)	F	Effect Size
Knowledge Area						
Remembering	259	30.4 (40.9)	126	30.0 (41.6)	0.0	__
Understanding	150	45.8 (41.9)	90	24.6 (42.0)	14.2 *	0.51
Application	67	31.1 (30.1)	285	16.5 (29.8)	12.7 *	0.49
Analysis	66	45.5 (48.5)		__	__	__
Evaluation		__	12	29.2 (49.8)	__	__
Total Score	299	34.4 (29.3)	285	18.2 (29.3)	44.3 *	0.55

* $p < .001$

Student Attitudes and Instructional Architecture

The results from this study suggest that students at the middle and secondary school level prefer to use WBLTs that present information in a relatively passive format and then test knowledge with a series of follow-up questions (direct instruction). This finding supports Kirschner et. al.'s (2006) claim that younger students may not be able to handle the cognitive demands of a constructive learning architecture. The challenge of open ended discovery, reflection on process, prediction, and self-guidance may have frustrated students and lead to lower student attitude ratings for a constructive-based architecture. It is also possible that students are more familiar with a direct instruction instructional architecture and therefore react more positively.

Key features that students preferred in WBLTs with a direct instruction architecture included visual supports, graphics, animations, organization, and help features. It is difficult to determine whether these features are inherent in the design of direct instruction WBLTs or simply reflect areas that the designers of constructivist-based WBLTs need to improve. To determine why students preferred a direction instruction over constructive-based instructional architecture, future researchers need to ask students about their preferred format of learning. In addition, qualitative data, perhaps in the form of open-ended questions, interview, and/or focus groups would help uncover the reasons for younger students' preferences in instructional architecture.

Student Performance and Instructional Architecture

Significant differences in favour of a direct instruction architecture were observed in understanding and application knowledge areas, but not remembering. This result was predicated by Kirschner et al. (2006), but is counter intuitive to theorists supporting a more constructivist approach to learning (e.g., Bruner, 1986; Papert, 1980; Steffe & Gale, 1995; Vannatta & Beyerbach, 2000; Vygotsky, 1978). It is relatively safe to conclude that differences between direct instruction and constructivist-based architectures were not due to gender, average grade, subject comfort level, and computer comfort level, because these potentially confounding variables were controlled for in the ANCOVA analysis. However, it is conceivable that the knowledge areas of understanding and application are better suited to a direct-instruction architecture. Kirschner et al. (2006) suggested that direction instruction might work better for basic level concepts. Higher level knowledge areas such as analysis and evaluation were rarely addressed by WBLTs in this study and might favour a constructive-based instructional architecture. Furthermore, the lesson plan time limit of 70 minutes may benefit the acquisition of basic concepts and the use of a direct instruction format. A constructive-based architecture might be best used over a longer period where there is more time to explore, test, and integrate knowledge. In summary, a direct instruction architecture may be more suitable to lower level knowledge areas such as understanding and application, however more research needs to be conducted on the use of direct instruction and constructive-base architecture on higher level knowledge areas such as analysis and evaluation tasks.

Caveats and Future Research

A number of procedures were followed to ensure the quality of data collection and analysis in this study including controlling for the design of WBLTs and lesson plans, using a wide range of WBLTs, employing reliable, valid data assessment tools, and assessing a wide range of learning performance knowledge areas. Nonetheless, several limitations remain and need to be addressed in future research.

First, the range of knowledge areas addressed by WBLTs should be expanded to include analysis and evaluation tasks. It is possible that different instructional architectures are suited toward acquiring different kinds of knowledge. Second, the design of lesson plans might need to be altered to address the additional time required to effectively implement a constructive-based WBLT. Third, more qualitative data in the form of interviews or focus groups would be useful in fleshing out why students prefer one instructional architecture over another. Finally, extraneous factors such as the quality of graphics and help features should be controlled for to better assess the impact of instructional architecture alone.

SUMMARY

This study examined middle and secondary school student attitudes and learning performance as a function of the instructional architecture for a WBLT. Students preferred WBLTs that followed a direct instruction format (vs. a constructive-based format), specifically in the areas of learning, design, and engagement. Qualitative evidence suggested that students perceived the direct instruction architecture as providing better organization and visual supports, higher quality graphics and animations, and superior help features. Students also performed better in understanding and application tasks with direct instruction architecture. It is speculated that a direct-instruction design may suit younger students who are learning basic level concepts. More research is needed to compare the impact of direct instruction vs. constructive-based architectures for higher level knowledge categories such as analysis and evaluation.

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