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Review of Different Assessment Methods Used by Online Inquiry-Based Learning Systems That Support Argumentation

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Abstract: The study aims to provide a current synthesis of assessment methods in Online Inquiry-Based Learning (OIBL) systems that use argumentation as a pedagogy. Three databases were used, namely, Scopus, Web of Science, and ERIC, for data collection. The present review analyzed 73 studies from 2010 to 2023. A qualitative content analysis examined the assessment methods used in inquiry-based systems. Results showed that most studies used direct methods of assessment followed by indirect methods. Among the direct method, more studies used the analysis of artefacts as an assessment method compared to the Multiple Choice Questions (MCQ) /short answer test. Among analysis of artefacts, most studies analyzed log files/chat/multimedia posts as artefacts followed by written arguments and video/audio recordings of interactions. Also, regarding MCQ/short answer tests, a majority of studies used achievement and conceptual understanding tests to assess student performance. Future studies need to use embedded assessment tools in their platform to increase learning opportunities for students. Also, future studies should enable synchronous and asynchronous access for teachers to student activities for proper assessment.

Keywords: Argumentation, Inquiry-based Learning, Online Argumentation, Assessment

1. Introduction

Inquiry-Based Science Education (IBSE) is an effective method for teaching science and fostering a scientific mindset (Van Uum et al., 2017). IBSE allows students to create research questions based on their scientific interests. Following that, students perform scientific investigations, examine results, and generate conclusions to answer their research questions (Lin, 2022). During inquiry, students develop explanations to make sense of data and then show them to their peers to discuss, critique, and revise. As a result, argumentation is also considered a practice of inquiry, which implies creating, justifying, and evaluating scientific explanations (Falk and Brodsky, 2013). Students engage in multiple aspects of inquiry to develop better explanations during argumentation. IBSE is believed to be a social construction of scientific knowledge via inquiry and argumentation with the scientific community (Sampson et al., 2011). With the rise of the internet, Online Inquiry-Based Learning (OIBL) tools have been developed to implement IBSE activities online. OIBL enhances scientific concepts and facts for long-term conceptual understanding. OIBL systems can improve students' performance in science classrooms (Alake-Tuenter et al., 2012).

Although prior studies suggest that OIBL systems improve student learning, middle school students still have trouble solving complex and data-rich problems (Sandoval, 2003). Students struggle to back up their claims with evidence-based arguments during IBL activities. To address this issue, researchers have employed OIBL systems with argumentation as a pedagogy. Also, studies have identified assessment tools/methods as an essential part of

instruction in OIBL systems (Su et al., 2011). Although Jha et al. (2023) presented a review of research regarding design features and learning outcomes in OIBL systems, a detailed analysis of assessment tools is not present in previous reviews (Donnelly et al., 2014; Zacharia et al., 2015; Jha et al., 2023). Thus, the current study aims to investigate assessment methods in OIBL systems.

2. Literature review

2.1 Inquiry and argumentation in online inquiry-based systems

Oliver (2008) defines IBL as an instruction method that uses a problem or activity to improve student engagement. Learning is the consequence of information processing that occurs when learners attempt to investigate the problem statement (Oliver, 2008). In scientific education, IBL aims to build high-quality explanations through argumentation (Falk and Brodsky, 2013). Numerous research have created OIBL systems to enhance students' academic achievement and competitive skills (Lau et al., 2017; Daley et al., 2016). Students liked such platforms, actively searched for knowledge online, and had meaningful conversations with their teachers and peers.

Argumentation is a key component of scientific thinking in education (Liu et al., 2019). Students use the OIBL system to complete IBL and knowledge-building tasks on the web. Questioning is an important component of inquiry and knowledge acquisition (Chin and Brown, 2002). According to Chin and Osborne (2008), questioning encourages scientific students to argue and think critically. IBL uses argumentation to build knowledge through comprehensive reasoning and questioning (Weinberger et al., 2007; Sampson et al., 2011). Sampson et al. (2011) developed an argument-driven inquiry framework to examine IBL and argumentation. The primary goal was to assist in creating online science learning programs. Throughout the argumentation process, students actively exchange perspectives and argue with their classmates about the evidence that supports certain premises. Weinberger et al. (2007) found that this approach improved students' reasoning abilities and domain-specific knowledge. Thus, argumentation in the OIBL system is crucial in developing a community of learners focused on collective concept improvement (Laru et al., 2012).

2.2 Motivation for the study

In light of the fact that argumentation plays a crucial role in argumentation and fostering scientific thinking and engagement through the OIBL system, it becomes crucial to evaluate the effectiveness of these educational strategies. Assessment methods adopted in the OIBL systems may be classified into two types: direct and indirect assessment methods (Elbeck and Bacon, 2015). Direct assessment methods require scoring learners' performance on a task believed to achieve a learning goal. For example, multiple-choice/short-answer tests, rubrics to assess artefacts, open-ended essays, and other tools. Indirect assessment approaches rely on ways other than looking at real examples of student work to gain information. Examples of such methods include student surveys, self-efficacy tests, and others (Elbeck and Bacon, 2015).

Multiple studies have designed OIBL systems, focusing on distinct features that enhance student learning. Syntheses by Donnelly et al. (2014) and Zacharia et al. (2015) explored the impact of IBL system features and guidance in science education. Further research by Coiro et al. (2018), Liu et al. (2021), and Jha et al. (2023) examined online collaborative inquiry, mobile technologies, and argumentation support alongwith learning outcomes in OIBL systems. Although one review by Jha et al. (2023) synthesized research on OIBL systems in terms of features that support argumentation and learning outcomes, there is a lack of review studies that focussed on assessment methods used by such systems. This is essential since educators and researchers can determine which assessment strategies best capture students' learning outcomes, critical thinking, and problem-solving skills developed

through inquiry-based activities. However, a comprehensive list of assessment methods is pending to date. The study answers the research question below.

- RQ: What are the different assessment methods used by the OIBL systems that support argumentation?

3. Method

3.1 Literature search

A systematic search method based on three concepts—Inquiry-based learning, argumentation, and online system—was adopted based on the well-established PRISMA (Liberati et al., 2009) framework. The study used three sets of keywords to look for research papers: 1. Inquiry-based learning related keywords, including inquiry learning, scientific inquiry, science inquiry, and collaborative inquiry learning; 2. Argumentation related keywords, including scientific argumentation and online argumentation; 3. Online system related keywords include computer-mediated communication, technology-enhanced learning, web-based systems, online learning, and web-based inquiry. Two keyword sets were combined using “AND” and “OR” within the set. Three databases, Scopus, Web of Science, and ERIC were searched for this review. The search focused on paper titles and abstracts from January 2010 to June 2023 to review assessment methods used by OIBL systems in the last decade.

3.2 Relevant publication search

The initial search yielded 3247 articles, including 1463 research papers from Web of Science, 1331 from Scopus, and 453 from the ERIC database. The next step involved filtering articles based on the inclusion and exclusion criteria described in Table 1. Jha et al. (2023) shows the flowchart and detailed filtering process of the articles. Finally, 73 articles were included in the final review.

Table 1. *Inclusion and exclusion criteria*

Inclusion criteria	Exclusion criteria
1. Available full text	1. Not written in English
2. Published in peer reviewed journals	2. No educational purpose, i.e., studies involving online discussions without any educational outcome
3. Articles that described any online/web-based system	3. Partial computer-assisted instructions with pen pencil activity
4. Articles that include experiments on focused study groups	4. Emphasize only on system design as opposed to learning outcome
5. Articles where students perform inquiry-based practices, create/share/critique evidence-based arguments/artefacts	

4. Results

The study analyzed 73 articles in the range from 2010 to June 2023. The complete list of selected publications and detailed metadata are presented in Jha et al. (2023). Each study was checked for assessment methods used in the platform and classified accordingly. In our review, most studies implemented direct assessment methods, while only five used indirect assessment. Direct assessment methods can also be further classified into multiple choice questions (MCQ), short answer tests, and analysis of artefacts, which could be further sub-classified into several modes of analysis as described below. Below, we have discussed platforms from the selected articles; a complete reference can be found in Jha et al. (2023).

4.1 Direct method: MCQ, short answer tests

Out of all the assessment methods, MCQ and short-answer tests are elementary to conduct and widely used. In our review, the learning achievement test (11 studies) was mainly used, followed by the conceptual understanding test (11 studies), content knowledge test (5 studies), and scientific competency/reasoning test (3 studies). The tests aim to assess individual students' learning performance, conceptual understanding, and content knowledge as they perform inquiry-based activities with the help of online platforms.

4.2 Direct method: analysis of artefacts

- *Open ended essay/report:* In our review, seven platforms (ASIS, WikiDiA, Nearpod Interactive classroom, TESI, GlobalEd2, VLE in Immunology, Edmodo and Bubble.us) used essays to assess multiple learning outcomes. Essays were scored based on a basic rubric to assess the quality of writing.
- *Written arguments:* In our review of literature, eleven studies (Flyer, CAWA, Comp-supp inquiry System, Dynamic climate models, Knowledge forum, WALE, iArgue, Moodle forum, Quandary, Go-Lab, POAL) analyzed written arguments as artifact to assess argumentation skill. Students answered open-ended questions to create arguments and were assessed using predesigned scoring rubrics.
- *Video/audio recording:* Ten studies analyzed video/audio recordings of students' interactions/discussions to measure several learning outcomes. Out of ten studies, five (Flyer, SSINet, Videogame, Young Archaeologist, Co-Lab) analyzed audiotaped discussions while another five (Smartphone & EBS forum, CoMPASS, ViBSE, AR-based Mobile learning, Crystal Island: EcoJourneys) analyzed video recordings.
- *Diagram/argument map:* Studies leveraged technological advancements to provide visualization support in diagrams, models, and argument maps. The above artefacts were also used to analyze students' work as they performed inquiry-based activities in online systems. In our review, two studies (e-ORDER and Smartphone with go-manage server) analyzed sketchy diagrams and five studies (Motion, Mindomo, PBL-AMOL, Vake, ABI application) analyzed concept maps to measure learning outcomes.
- *Log files/chat/multimedia posts:* Multiple studies analyzed multimedia items in forum posts, chats, and log files to measure different learning outcomes. Two studies (Habitat Tracker and InterLace) analyzed multimedia posts in forums, six studies (ASIS, WISE, Motion, Co-Lab, Knowledge forum, Collisions) analyzed chat/comments, and four studies (Research Quest, Young Archaeologist, Crystal Island: EcoJourneys, The New Frog VPA) analyzed log files of interactions.

4.3 Indirect method: survey, self-efficacy

Regarding indirect assessment methods, our review indicates that three studies (GlobalEd2, Nearpod Interactive classroom and EcoMUVE) assessed self-efficacy, two studies (Smartphone with go-manage server; TESI) used a survey questionnaire, and one study (OPASS) used a degree of satisfaction questionnaire as assessment tool. These methods use questionnaires featuring Likert scale questions to evaluate students' understanding.

5. Discussion

Our review identified two types of assessment methods, namely, direct and indirect assessment methods. Only 8% of studies used indirect assessment methods consisting of surveys and self-efficacy questionnaires. Nearly all studies used direct assessment methods, consisting of MCQ/short answer tests and analysis of artefacts. Our review of MCQ/short answer tests identified that most studies used the learning achievement test as an assessment

tool, followed by the conceptual understanding and content knowledge tests. The above tests are frequently used since they are easier to design, conduct, and analyze. Among analysis of artefacts, most studies used log files of chat and multimedia posts to measure several learning goals followed by written arguments, video/audio recordings of interactions, diagrams, and essays. The review identified that more systems analyzed rhetoric argumentation (written arguments) than dialogical argumentation (video, audio, and chat interactions).

Further, several OIBL systems support multiple-choice/short questions, but few utilize embedded assessments like argument maps, diagrams, and essays. Standard assessment methods may not fully capture students' learning achievements (Hickey et al., 2012; Donnelly et al., 2014). Thus, future studies should include embedded assessment tools, as it can enhance learning opportunities (Hickey et al., 2012). In addition, only two OIBL systems allow remote teacher review of student activities and artefacts (Looi et al., 2011; Pedaste and Sarapuu, 2014). Remote teacher access can help students who struggle with inquiry or argumentation activities and improve assessment. Future OIBL systems should enable synchronous and asynchronous teacher review to support students effectively.

6. Conclusion, limitation, and direction for future work

The current study synthesized assessment methods in argument-supported OIBL systems and highlights areas for future research. Data from 73 research publications between 2010 and June 2023 was analyzed in this study. The study identified two types of assessment methods: direct and indirect. Most studies used direct assessment methods such as MCQ/short answer tests and analysis of artefacts, while few studies used indirect assessment methods consisting of surveys and self-efficacy questionnaires. The implications of this study include integrating embedded assessment tools and enabling teacher reviews in OIBL systems to support student learning. Adopting diverse assessment methods can provide a more comprehensive evaluation of students' skills and knowledge.

The review had several limitations. First, the study searched and identified relevant publications using PRISMA guidelines to ensure papers were selected. However, there are still some publications that might not make it into our final list. Second, we did not include partial computer-assisted OIBL systems that supported pen-pencil activity. Future studies should incorporate these systems to investigate how they affect argumentation and other learning outcomes. Finally, our study presented types of assessment tools but did not focus on the quantitative study regarding features of such tools (e.g., questions used in tests, types of rubrics for analysis, etc.). Further, studies should explore the features of assessment tools in more detail.

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