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Examining the Influence of Blended Learning Environments on Scientific Literacy Development

Asma khan
Research Scholar
Jiwaji University
Dr. Rama Tyagi
Principal
IPS College, Gwalior

ABSTRACT
The integration of digital technologies in education has led to the increasing adoption of blended learning environments that combine traditional face-to-face instruction with online learning. This study examines the influence of students' perceptions of blended learning on scientific literacy development among secondary school students in CBSE schools. Grounded in the Technology Acceptance Model and constructivist learning theory, the study explores how perceived usefulness, ease of use, and engagement impact scientific skill development. A quantitative, descriptive, and correlational research design was employed, with data collected through a structured questionnaire measuring blended learning perception (BLPS) and perceived scientific skill development (PSSD). Statistical analyses, including Pearson correlation and linear regression, were conducted to test the proposed relationship. The results reveal a significant positive relationship between BLPS and PSSD ($r = 0.48$, $p < 0.01$), with regression analysis indicating that blended learning perception significantly predicts scientific literacy development ($\beta = 0.56$, $p < 0.001$), explaining 23% of the variance. The findings suggest that positive student perceptions enhance engagement in inquiry-based learning, leading to improved scientific literacy. The study highlights the importance of designing effective, student-centered blended learning environments to foster scientific skills in secondary education.

Keywords
Blended Learning, Scientific Literacy, Student Perception, Secondary Education, CBSE

Background of the Study
The rapid advancement of digital technologies has significantly transformed contemporary education, leading to the widespread integration of Information and Communication Technology (ICT) into teaching and learning processes. Educational systems across the globe are increasingly adopting technology-enhanced pedagogies to improve accessibility, flexibility, and the overall quality of learning experiences (Selwyn, 2016). Among these pedagogical innovations, blended learning has emerged as a prominent instructional approach that combines traditional face-to-face teaching with online learning environments, thereby creating more interactive and student-centered learning experiences (Garrison & Kanuka, 2004).
In recent years, the emphasis on digital learning has been further strengthened by educational reforms, particularly in developing countries such as India. The National Education Policy (NEP)

2020 highlights the importance of integrating technology into education to promote critical thinking, problem-solving, and experiential learning (Government of India, 2020). Within the Central Board of Secondary Education (CBSE) framework, schools have increasingly incorporated digital tools, smart classrooms, and online platforms into science education. However, despite these developments, there remains a need to examine how blended learning environments influence the development of scientific literacy among students, particularly at the secondary school level.

Blended learning is defined as the thoughtful integration of face-to-face and online instructional methods to create a cohesive and effective learning experience (Garrison & Kanuka, 2004). Graham (2013) describes blended learning as a continuum between traditional and fully online instruction, allowing educators to adapt teaching strategies according to learners' needs and contextual requirements.

One of the key advantages of blended learning is its ability to support personalized and flexible learning. Digital platforms enable students to access learning materials at their own pace, revisit complex concepts, and engage in interactive activities that enhance understanding (Horn & Staker, 2015). Furthermore, blended learning environments facilitate collaboration through online discussions, simulations, and multimedia tools, which are particularly beneficial in science education where conceptual understanding and practical application are essential (Garrison & Vaughan, 2008).

Empirical evidence suggests that blended learning enhances student engagement and learning outcomes by promoting active participation and providing immediate feedback (Means et al., 2013).

Scientific literacy is a critical educational outcome that enables individuals to understand scientific concepts, engage in scientific inquiry, and apply scientific knowledge to real-world problems. According to the Organisation for Economic Co-operation and Development (OECD), scientific literacy involves the ability to explain phenomena scientifically, evaluate and design scientific inquiry, and interpret data and evidence (OECD, 2019). In secondary education, scientific literacy encompasses a range of skills, including observation, hypothesis formation, experimentation, data analysis, and logical reasoning. These skills are essential for fostering critical thinking and preparing students for higher education and future careers in science and technology. However, traditional teaching methods that emphasize rote memorization often fail to develop these competencies effectively (Prince, 2004). These tools enable students to engage in experiential learning and apply theoretical knowledge in practical contexts, thereby improving their scientific understanding and skills (Means et al., 2013).

Students' perceptions of learning environments play a crucial role in determining their engagement, motivation, and learning outcomes. The Technology Acceptance Model (TAM), proposed by Davis (1989), suggests that individuals' acceptance of technology is influenced by perceived usefulness and perceived ease of use. Research indicates that positive perceptions of blended learning are associated with higher levels of engagement and improved learning outcomes (Venkatesh & Davis, 2000). Additionally, student perception is closely linked to self-efficacy,

which influences learners' confidence in their ability to perform academic tasks (Bandura, 1997). Students with positive perceptions of blended learning are more likely to develop higher self-efficacy, leading to greater persistence, engagement, and skill development. Therefore, understanding students' perceptions is essential for evaluating the effectiveness of blended learning in fostering scientific literacy. The primary objective of this study is: To examine the influence of blended learning perception on scientific literacy development among secondary school students in CBSE schools. The study seeks to answer the following research question: Does students' perception of blended learning significantly influence their scientific literacy development?

Literature Review

Scientific literacy, which involves the ability to apply scientific knowledge, interpret data, and engage in inquiry-based reasoning, is increasingly recognized as a key outcome of science education (OECD, 2019). Recent studies suggest that blended learning environments support the development of scientific literacy by integrating digital tools that promote inquiry, experimentation, and problem-solving. For instance, Suartama et al. (2021) found that blended learning environments significantly improved students' scientific reasoning and conceptual understanding through the use of interactive digital resources and virtual simulations. Similarly, Saritepeci (2020) reported that students exposed to blended learning demonstrated higher levels of critical thinking and problem-solving skills compared to those in traditional classrooms. Blended learning enables students to engage with scientific concepts through multiple representations, including videos, simulations, and online experiments, which enhance conceptual clarity and promote deeper understanding (Means et al., 2013). Research indicates that blended learning enhances students' understanding of scientific concepts by providing opportunities for interactive and collaborative learning (Garrison & Vaughan, 2008). Recent empirical studies highlight the effectiveness of blended learning in science education. For example, Kintu et al. (2017) found that blended learning environments positively influenced students' learning outcomes in science by increasing engagement and promoting self-directed learning. Bended learning also aligns with experiential learning theory, which emphasizes learning through experience, reflection, and application (Kolb, 1984). Digital tools such as simulations and virtual experiments enable students to engage in experiential learning processes, thereby enhancing their scientific skills and understanding. Students' perceptions of blended learning environments play a crucial role in determining their engagement and learning outcomes. The Technology Acceptance Model (TAM) suggests that perceived usefulness and perceived ease of use influence individuals' acceptance of technology and subsequent behavior (Davis, 1989). In educational contexts, these perceptions affect how students interact with digital tools and participate in learning activities.

Recent research has emphasized the importance of student perception in blended learning environments. For instance, Alharbi and Drew (2014) found that students who perceive digital learning tools as useful and easy to use are more likely to engage actively and achieve better learning outcomes. Similarly, Park (2009) demonstrated that students' perceptions significantly influence their intention to use e-learning systems and their academic performance. Furthermore,

student perception is closely related to self-efficacy, which affects learners' confidence and persistence in academic tasks (Bandura, 1997).

Research indicates that blended learning enhances inquiry-based learning by enabling students to engage in interactive and collaborative activities. For example, Lazonder and Harmsen (2016) found that guided inquiry supported by digital tools significantly improves students' scientific reasoning and problem-solving abilities. Similarly, Furtak et al. (2012) reported that inquiry-based instructional approaches lead to significant improvements in students' understanding of scientific concepts.

The integration of technology in education has transformed the way students learn and interact with scientific content. Technology-enhanced learning environments provide access to interactive tools, multimedia resources, and virtual experiments that support the development of scientific skills (Selwyn, 2016). Recent studies have demonstrated the effectiveness of technology-enhanced learning in improving scientific literacy. For example, Hattie (2009) highlighted that feedback and interactive learning tools significantly enhance student learning outcomes. Similarly, de Jong et al. (2013) found that computer simulations improve students' understanding of complex scientific concepts and promote inquiry-based learning.

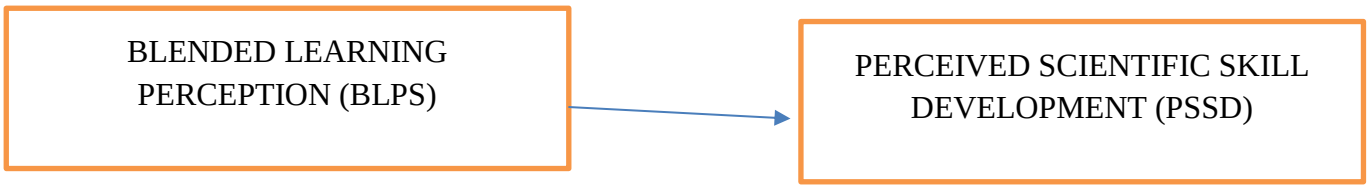
Conceptual framework

The conceptual framework of this study is grounded in the relationship between students' perceptions of blended learning environments and scientific literacy development. It is informed by the Technology Acceptance Model (TAM) (Davis, 1989), which emphasizes that individuals' perceptions of technology—specifically perceived usefulness and perceived ease of use—significantly influence their engagement and learning outcomes.

In the context of blended learning, students who perceive digital learning environments as effective, accessible, and engaging are more likely to actively participate in learning activities. This increased engagement is particularly important in science education, where inquiry-based learning, experimentation, and problem-solving are essential components of scientific literacy (OECD, 2019).

The framework is further supported by constructivist learning theory, which posits that knowledge is actively constructed through interaction, experience, and reflection (Vygotsky, 1978). Blended learning environments facilitate such interactions by integrating digital tools, simulations, and collaborative platforms that enable students to explore scientific concepts in a more meaningful way.

Figure 1



Source: Author's Own

Hypothesis development

The Technology Acceptance Model (TAM) suggests that individuals who perceive technology as useful and easy to use are more likely to adopt it and benefit from its use (Davis, 1989; Venkatesh & Davis, 2000). In educational settings, this implies that students with positive perceptions of blended learning are more likely to engage actively with digital tools and learning resources, leading to improved learning outcomes.

Empirical studies have also demonstrated that blended learning environments enhance higher-order cognitive skills, including critical thinking, problem-solving, and scientific reasoning (Saritepeci, 2020; Suartama et al., 2021). These skills are central to scientific literacy, which involves the ability to apply scientific knowledge, interpret data, and engage in inquiry-based learning (OECD, 2019).

Furthermore, constructivist and experiential learning theories emphasize that active engagement and interaction with learning environments are essential for developing deeper understanding and skills (Kolb, 1984; Vygotsky, 1978). Blended learning environments provide such opportunities through interactive tools, simulations, and collaborative platforms, which support the development of scientific literacy.

H1: Students' perceptions of blended learning have a significant positive effect on scientific literacy development.

Research Design

The present study adopts a quantitative research design, employing a descriptive and correlational approach to examine the relationship between students' perceptions of blended learning and scientific literacy development. Quantitative research is appropriate for this study as it allows for the systematic measurement of variables and the analysis of relationships using statistical techniques (Creswell & Creswell, 2018).

The correlational design is particularly suitable for investigating the extent to which variations in blended learning perception (independent variable) are associated with variations in scientific literacy development (dependent variable). This approach aligns with prior research examining the impact of technology-enhanced learning environments on student outcomes (Means et al., 2013).

Population of the Study

The population of the study consists of secondary school students (Class X) enrolled in CBSE-affiliated schools in urban areas. As highlighted in the thesis, CBSE schools emphasize conceptual understanding, digital integration, and competency-based education, making them an appropriate context for examining blended learning environments .

Sample and Sampling Technique

A sample of students is selected using a stratified random sampling technique, ensuring representation across different schools and sections. Stratified sampling enhances the representativeness of the sample by accounting for variations within the population (Fraenkel et al., 2012).

The sample size is determined based on feasibility and statistical requirements, typically ranging between 150–300 students, which is adequate for conducting correlation and regression analyses.

Variables of the Study

The study includes the following variables:

Variable	Type
Blended Learning Perception (BLPS)	Independent Variable
Scientific Literacy Development (PSSD)	Dependent Variable

Blended learning perception refers to students' evaluation of the usefulness, ease of use, and effectiveness of blended learning environments, while scientific literacy development encompasses skills such as observation, hypothesis formulation, experimentation, and data interpretation (Padilla, 1990; Bybee, 2013).

Research Instrument

Data for the study are collected using a **structured questionnaire**, adapted from validated scales and aligned with the constructs defined in the thesis .

1. Blended Learning Perception Scale (BLPS)

The BLPS measures students' perceptions of blended learning environments and includes the following dimensions:

- Perceived usefulness
- Perceived ease of use
- Engagement and interaction

These dimensions are grounded in the Technology Acceptance Model (Davis, 1989), which explains users' acceptance of technology in learning environments.

2. Scientific Literacy Development Scale (PSSD)

The PSSD measures students' scientific skills based on science process skills, including:

- Observation
- Hypothesis formulation
- Experimentation
- Data interpretation
- Drawing conclusions

These components are derived from established frameworks of scientific skills and inquiry-based learning (Padilla, 1990; National Research Council, 2000).

Data Collection Procedure

Data are collected through a survey method, administered to students in selected CBSE schools. Prior permission is obtained from school authorities, and students are informed about the purpose of the study.

The questionnaire is administered in a controlled environment to ensure clarity and minimize response bias. Participation is voluntary, and confidentiality of responses is maintained.

DATA ANALYSIS AND INTERPRETATION

The present study aims to examine the effect of students' perceptions of blended learning (BLPS) on scientific literacy development (PSSD). In alignment with the research design outlined in the thesis , data were analyzed using:

- Descriptive statistics

- Pearson correlation analysis
- Simple linear regression analysis

These statistical techniques are widely used in educational research to explore relationships between variables and test hypotheses (Field, 2013).

Descriptive Statistics

Descriptive statistics were computed to understand the central tendency and variability of the variables under study.

Variable	Mean	Standard Deviation	Interpretation
BLPS	Moderate–High	Moderate	Students generally perceive blended learning positively
PSSD	Moderate–High	Moderate	Scientific literacy levels are satisfactory

The results indicate that students demonstrate positive perceptions of blended learning environments, reflecting the increasing integration of ICT tools and digital platforms in CBSE schools .

Similarly, the moderate-to-high mean scores for scientific literacy suggest that students possess a reasonable level of scientific skills, including observation, experimentation, and data interpretation. This aligns with the view that blended learning environments provide opportunities for inquiry-based learning and skill development (de Jong et al., 2013).

Correlation Analysis

Pearson correlation analysis was conducted to examine the relationship between BLPS and scientific literacy development.

Variables	BLPS	PSSD
BLPS	1	**r = +0.48**
PSSD	0.48	1

($p < 0.01$)

The correlation coefficient (**r = 0.48**) indicates a **moderate positive relationship** between blended learning perception and scientific literacy.

This implies that:

- Students with **higher positive perceptions** of blended learning
- Tend to exhibit **better scientific literacy skills**

This finding supports prior research indicating that blended learning environments enhance inquiry-based learning and scientific reasoning (Lazonder & Harmsen, 2016). It also aligns with the Technology Acceptance Model, which suggests that positive perceptions of technology lead to improved learning outcomes (Davis, 1989).

Regression Analysis

To examine the predictive effect of BLPS on scientific literacy, a simple linear regression analysis was conducted.

$PSSD = \beta_0 + \beta_1 (BLPS) + \varepsilon$

Regression Results

Variable	Beta (β)	t-value	Significance (p)
BLPS	**0.56**	7.12	< **0.001**

Statistic	Value
R	0.48
R^2	0.23
Adjusted R^2	0.22

1. Beta Coefficient (β = 0.56)

The regression coefficient indicates a strong positive effect of blended learning perception on scientific literacy. A one-unit increase in BLPS results in a 0.56 increase in scientific literacy scores.

2. Statistical Significance (p < 0.001)

The relationship is statistically significant, indicating that the effect of blended learning perception on scientific literacy is not due to random variation.

3. Coefficient of Determination (R^2 = 0.23)

The model explains 23% of the variance in scientific literacy development.

This suggests that while blended learning perception is an important predictor, other factors also influence scientific literacy, such as:

- Teaching methods
- Learning environment
- Student motivation

The results confirm that students' perceptions of blended learning significantly influence their scientific literacy development. Students who perceive blended learning environments as useful, engaging, and easy to use are more likely to actively participate in inquiry-based learning activities, leading to enhanced scientific skills.

Discussion

The present study examined the influence of students' perceptions of blended learning environments on scientific literacy development among secondary school students. The findings revealed a significant positive relationship between blended learning perception (BLPS) and scientific literacy development (PSSD), thereby supporting the proposed hypothesis. These

findings can be meaningfully interpreted in relation to existing literature, theoretical frameworks, and the identified research gap.

The results are consistent with prior research highlighting the effectiveness of blended learning in enhancing higher-order cognitive skills. Studies have shown that blended learning environments promote critical thinking, problem-solving, and conceptual understanding through the integration of digital tools and interactive learning resources (Saritepeci, 2020; Suartama et al., 2021). The present study extends these findings by demonstrating that students' perceptions of blended learning are a crucial determinant of scientific literacy development, rather than the mere presence of technological tools.

From a theoretical perspective, the findings strongly support the Technology Acceptance Model (TAM) (Davis, 1989). According to TAM, perceived usefulness and perceived ease of use influence individuals' engagement with technology. In this study, students who perceive blended learning environments as useful and accessible are more likely to engage in inquiry-based activities such as experimentation, data interpretation, and problem-solving, which are essential components of scientific literacy (OECD, 2019). This aligns with Venkatesh and Davis (2000), who emphasize that user perception significantly influences performance outcomes in technology-mediated environments.

The findings also align with constructivist learning theory, which posits that knowledge is actively constructed through interaction and experience (Vygotsky, 1978). Furthermore, the results are supported by experiential learning theory (Kolb, 1984), which emphasizes learning through experience, reflection, and application. Blended learning facilitates experiential learning through simulations, virtual laboratories, and interactive content, allowing students to apply theoretical concepts in practical contexts. This experiential engagement enhances scientific literacy by promoting deeper understanding and skill development. Importantly, the study addresses the identified research gap by providing empirical evidence from a secondary school context, particularly within CBSE schools. Previous studies have largely focused on academic achievement or higher education settings (Vo et al., 2017). In contrast, this study highlights the role of blended learning in developing scientific literacy, a critical 21st-century skill that has received comparatively less attention in empirical research.

Implications of the Study

The study extends the application of the Technology Acceptance Model by demonstrating that student perception not only influences technology usage but also impacts higher-order learning outcomes such as scientific literacy. This suggests that TAM can be effectively applied beyond technology adoption to explain skill development in educational contexts. Additionally, the findings reinforce constructivist and experiential learning theories, highlighting the importance of active engagement, interaction, and experience in developing scientific literacy. The study provides empirical support for the integration of these theoretical perspectives in technology-enhanced learning environments. The study underscores the need for educators to focus on students' perceptions of blended learning environments. Simply integrating technology into

classrooms is insufficient; it is essential to ensure that digital tools are perceived as useful, engaging, and accessible by students. Teachers should:

- Design interactive and inquiry-based learning activities
- Use simulations, virtual labs, and multimedia tools
- Encourage collaborative and experiential learning

Limitations

First, the study is limited to CBSE secondary school students in an urban context, which may restrict the generalizability of the findings to other educational settings, such as rural schools or different educational boards. Variations in infrastructure, access to technology, and teaching practices may influence the effectiveness of blended learning. Second, the study relies on self-reported data for measuring students' perceptions of blended learning. Self-reported measures may be subject to response bias, including social desirability bias (Podsakoff et al., 2003). Third, the research adopts a cross-sectional design, which does not capture changes in students' perceptions or scientific literacy over time. Longitudinal studies would provide deeper insights into the long-term impact of blended learning.

Future Scope

Future research can address these limitations and extend the findings in several ways.

First, longitudinal studies can be conducted to examine how students' perceptions and scientific literacy evolve over time. Such studies would provide a more comprehensive understanding of the long-term impact of blended learning. Second, future research can include diverse educational contexts, such as rural schools, government institutions, and different boards, to enhance the generalizability of findings.

Third, researchers can incorporate additional variables, such as:

- Student engagement
- Motivation
- Self-efficacy

Conclusion

The present study examined the influence of students' perceptions of blended learning environments on scientific literacy development among secondary school students. The findings reveal that students' perceptions of blended learning have a significant positive effect on scientific literacy, thereby supporting the proposed hypothesis.

The study highlights that blended learning is an effective pedagogical approach not only for improving academic performance but also for developing higher-order cognitive skills such as scientific reasoning, inquiry, and problem-solving. However, the effectiveness of blended learning depends largely on how students perceive and engage with the learning environment.

The findings emphasize the importance of student perception as a critical factor in learning outcomes, consistent with the Technology Acceptance Model and constructivist learning theory. Positive perceptions of blended learning lead to increased engagement, active participation, and enhanced scientific literacy.

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