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A Study of Differences in Higher-order Thinking Skills among Higher Education in Blended Learning

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Abstract

The purpose of this study was to investigate the differences in higher-order thinking skills (HOTS), learning interactions (LI), learning feedback (LF), and learning self-efficacy (LS) among undergraduates taking an advanced mathematics course in a blended learning (BL) environment. It was quantitative and used a descriptive survey with a sample size 461. Independent sample t-tests and one-way analysis of variance tests were also used for inferential analysis. The results showed no statistically significant disparities in learning feedback and self-efficacy. Additionally, there were statistically significant differences in four dimensions- learning interaction, learning feedback, HOTS, and self-efficacy at the grade level. The study also found statistically significant differences in the dimensions of learning feedback and self-efficacy among college students in different age groups. However, no significant differences were found in learning interaction and higher-order thinking dimensions. Lastly, no statistically significant differences exist in the four dimensions of learning interaction, learning feedback, HOTS, and self-efficacy among students with different chemistry majors.

Keywords: Higher-Order Thinking Skills, Blended Learning, Learning Interaction, Learning Self-Efficacy, Learning Feedback

Introduction

China Education Modernisation 2035 puts forward the strategic decision to "strengthen the cultivation of innovative talents, especially top-notch innovative talents". Developing students' advanced cognitive skills within educational settings has become a significant advancement in promoting the growth of innovative individuals, as it is essential for fostering creativity and uniqueness (Yulian & Yueguang, 2017). In China, the curriculum standards based on core literacy also emphasize the cultivation of higher-order thinking in subject-teaching practices, which has become the key to classroom teaching in the new era (Jingying et al., 2023). Higher-order thinking is also a fundamental demand of the goal of science education, and the contemporary reform of science education has upgraded the teaching of lower-order cognitive skills from traditional concepts to HOTS, such as scientific inquiry, reasoning, argumentation, and collaborative communication (FitzPatrick & Spiller, 2010).

To successfully navigate the complexities and obstacles of the twenty-first century, one must possess HOTS (Mustika et al., 2020; Wijers & de Haan, 2020). Enhancing HOTS has also emerged as a top priority in mathematics education. The history of HOTS discussions in educational psychology is extensive. Rather than focusing solely on accumulating knowledge, numerous academics have argued that education should emphasize higher levels of learning through analysis, synthesis, and evaluation. Furthermore, these individuals have advocated developing HOT skills as a natural byproduct of learning and teaching (Bloom et al., 1956; Vygotsky & Cole, 1978).

For students to succeed in today's fast-paced world, they need to have a robust set of abilities. In the modern, fast-paced world, it is necessary to have creative thinking, critical thinking, and the ability to solve problems. The role of HOTS is vital in today's era of the fourth industrial revolution. HOTS refers to the ability to trust and rely on the cognitive processes used for analyzing, evaluating, and creating. As per the research, it has been found that learning environments that prioritize the needs of students play a significant role in fostering HOTS and critical-analytic thinking. These two types of thinking have several similarities.

Students must acquire robust abilities to succeed in today's fast-paced world. It is essential to possess abilities like creativity, critical thinking, and problem-solving in today's fast-paced society (Rahman, 2019). In the current fourth industrial revolution age, the role of HOTS is crucial, as Eliyasni et al. (2019) and Minarni and Napitupulu (2020) noted. The ability to rely on and have faith in the cognitive processes involved in analysis, evaluation, and creation is referred to as HOTS. HOTS and critical-analytic thinking are largely fostered by learning environments that put students' needs first, according to a study by Loyens et al. (2023). There are numerous parallels between these two ways of thinking.

BL is becoming increasingly accepted in many educational institutions as the norm for delivering core curricula (Smith & Francis, 2022). Higher education has also given BL much attention to increasing learning effectiveness and efficiency (Kelly et al., 2021). A growing number of academic institutions are using BL, which combines technology-based instruction with traditional classroom instruction (Porter et al., 2014). Higher education institutions increasingly use blended learning because of its adaptability, digital capabilities, and accessibility. Researchers have projected that BL holds enormous potential for universal adoption in higher education (Norberg et al., 2011) and can revolutionize traditional face-to-face learning as the concept of formal paradigm-shifting evolves (Al-Samarraie et al., 2013; Nunan et al., 2000).

An innovative learning model created by Prahani et al. (2020) can potentially raise students' HOTS. Using the Mobile Learn application in every learning activity, the BWML (Blended Web Mobile Learning) Paradigm is a learning model that combines the PBL and Hybrid Learning models. The effectiveness of implementing STEM-blended learning to improve high school students' high-level thinking skills on the Kepler law notion during the COVID-19 outbreak was investigated by Haryadi et al. (2021) using a quasi-experimental technique. A quasi-experiment was created by Hariadi et al. (2022) to examine how well the blended online mobile learning approach improved high school students' learning outcomes based on HOTS.

It has come to everyone's attention that there is a significant gender difference in the fields of science, technology, engineering, and mathematics (STEM), but it is becoming more and more apparent that not all STEM fields are created equal in terms of gender discrepancies (Cimpian et al., 2020; Wang & Degol, 2017). In the United States, there is still a problem with the underrepresentation of women in STEM degrees with high mathematical content (Yulian & Yueguang, 2017). According to a study by Bai et al. (2023), there was no significant difference between the sexes in the students' higher-order mathematical reasoning ability. The gender differences in mathematics performance in HOTS—applying skills, reasoning skills, and both—among Malaysian international school students in grade four were examined by Kashefi et al. (2017). The findings indicated that there is no statistically significant gender difference.

Nevertheless, a multinomial logistic analysis and a latent profile analysis were carried out by Chae & Lee (2018). According to the latent profile analysis, four classes might be distinguished by using HOT skills (i.e. a type for lower-order thinking, a class for creative-argumentative review, a class for analytical-caring thinking, and a class for higher-order thinking.). The factors that determined the latent profile types were year, gender, and instructional strategy. However, when academic subjects were considered, no disparities were found. Lower-year students were more likely to be enrolled in lower-order thinking classes. These studies differ in terms of gender differences in HOTS.

Research objective

The main goal of this article is to demonstrate how significant variations in HOTS in mathematics study in a blended learning environment are affected by factors such as gender, age, grade, and other factors. Since learning variables, including learning interactions, learning feedback, and learning self-efficacy, all favourably influence the development of HOTS, our second goal was to ascertain whether there are gender, grade, age, and major differences in these areas (Hj. Ebil et al., 2020; Huang et al., 2023; Sun et al., 2022). Making recommendations for further study to broaden our knowledge of gender, grade, age, and major issues in the development of HOTS is the last stage.

Requestion 1. Does the gender of college students taking advanced mathematics courses in a blended learning environment make a difference in HOTS, learning interaction, learning feedback, and learning self-efficacy?

Requestion 2. Do the grades of college students taking advanced mathematics courses in a blended learning environment make a difference in HOTS, learning interaction, learning feedback, and learning self-efficacy?

Requestion 3. Does the age of college students taking advanced mathematics courses in a blended learning environment make a difference in HOTS, learning interaction, learning feedback, and learning self-efficacy?

Requestion 4. Do college students' majors taking advanced mathematics courses in a blended learning environment make a difference in terms of HOTS, learning interaction, learning feedback, and learning self-efficacy?

Methodology

This study concentrated on the descriptive survey method and employed a quantitative approach. It was held in the middle of China at a Normal University. To decide who would participate in the study, the researchers used a straightforward random sampling approach. According to Krejcie & Morgan's (1970) table, 461 undergraduate students participated in this study as respondents. Table 1 displays the respondents' profiles.

The study's dependent variables were the pupils' HOTS. In advanced mathematics courses, the demographic variables of gender, age, grade, and major were declared as independent variables. This was because the researchers sought to see if the demographic data had any

bearing on learning interaction, learning self-efficacy, learning feedback, and HOTS from each of the four perspectives.
A series of closed-question questionnaires using the Likert scale were employed to gather data on learning interaction, learning self-efficacy, learning feedback, and learning HOTS. This study used the Statistical Package for Social Science (SPSS) version 27.0 for data analysis, applying descriptive and inferential statistics. Descriptive statistics that examined frequency, percentage, and mean values were used to analyze the learning interaction, learning self-efficacy, learning feedback, and learning HOTS for each component. The researchers used one-way analysis of variance tests (ANOVA) and independent sample t-tests to determine the impact of each demographic factor on the dependent variable.

Participants
Participants were undergraduate students who had taken advanced mathematics courses in a blended learning environment. The participants are undergraduate students with a range of genders, ages, majors, and grades, as shown in Table 1. Of them, 60.1 % (277) are female and 39.9 % (184) are male. Among them were 184 (39.9%) freshmen, 172 (37.3%) sophomores, and 105 (22.8%) juniors. Merely 3% of students major in material chemistry, 15% in environmental science, and 50.8% in chemistry, with 234 students majoring in chemistry. 238 (51.6%) of the sample are between the ages of 20 and 21, 160 (34.7%) are between the ages of 18 and 19, 61 (13.2%) are between the ages of 22 and 23, and just 2 (0.4%) are older than 24.

Table 1
Demographic information of the participants

Demographic Factors	Frequency(n)	(%)
Gender		
male	184	39.9
female	277	60.1
Grade		
Freshman	184	39.9
Sophomore	172	37.3
Junior	105	22.8
Age		
18~19	160	34.7
20~21	238	51.6
22~23	61	13.2
24~25	2	0.4
Major		
Material chemistry	14	3
Chemistry	234	50.8
Environmental Science	73	15.8
Applied Chemistry	140	30.4

Results

Table 2

The results of variance analysis and difference test of HOTS ability of college students under blended learning of higher education

Dimension	Gender		F	P	Cohen's d
	Male(*n*=184)	Female (*n*=277)			
LI	2.5685(0.91334)	2.4433(0.70289)	9.796	0.02	0.15
LF	3.8071(1.15121)	4.0018(1.06087)	1.979	0.16	------
HOTS	3.3817(1.00587)	3.3718(0.77832)	9.781	0.02	0.01
LS	3.604(0.74802)	3.7538(0.69504)	2.108	0.147	-----

Independent sample t-tests were employed to identify significant gender differences among college students in HOTS and learning interactions. In contrast, no statistically substantial learning feedback and self-efficacy disparities were observed. Following Cohen's classification of effect sizes, small, medium, and large effect sizes are defined as d = 0.2, 0.5, and 0.8, respectively (Cohen, 1992). When combining the data analysis results, it was observed that boys exhibited significantly higher performance than girls in learning interaction and higher-order thinking dimensions with a small effect size.

Table 3

A one-way ANOVA analysis of grade

Dimension	Grade			F	P	η^2
	Freshman(*n*=184)	Sophomore(*n*=172)	Junior(*n*=105)			
LI	2.413(0.799)	2.455(0.742)	2.697(0.844)	4.665	0.010	0.02
LF	4.170(1.081)	3.724(1.008)	3.821 (1.203)	8.133	0.000	0.034
HOTS	3.530 (0.909)	3.211 (0.758)	3.375 (0.951)	6.035	0.003	0.026
LS	3.815 (0.753)	3.643 (0.622)	3.566(0.781)	4.788	0.009	0.02

A one-way ANOVA analysis of grades revealed statistically significant differences among college students in four dimensions: learning interaction, learning feedback, HOTS, and self-efficacy at the grade level. Post hoc tests indicated that first-year students scored significantly higher than juniors and sophomores on the HOTS dimension, with a small effect size. On the learning interaction dimension, juniors outperformed sophomores significantly, while sophomores performed better than first-year students. First-year students achieved significantly higher scores than juniors on learning feedback and higher-order thinking dimensions with a small effect size. Similarly, juniors scored considerably better than sophomores on these two dimensions. In terms of self-efficacy, first-year students obtained significantly higher scores than their junior counterparts, outperforming sophomores with a small effect size.

Table 4
A one-way ANOVA analysis of age

Dimension	Age				F	P	η2
	18~19(*n*=160)	20~21(*n*=238)	22~23(*n*=61)	24~25(*n*=2)			
LI	2.396(0.796)	2.537(0.794)	2.574 (0.790)	2.600 (0.849)	1.257	0.289	1.257
LF	4.083 (1.053)	3.819 (1.098)	3.955 (1.196)	2.750 (0.354)	2.630	**0.050**	2.630
HOTS	3.439 (0.913)	3.373 (0.867)	3.237 (0.807)	2.885 (0.490)	1.004	0.391	1.004
LS	3.810 (0.713)	3.701 (0.697)	3.390 (0.742)	2.900 (0.141)	6.021	**0.000**	6.021

A one-way ANOVA analysis of age revealed statistically significant differences in the dimensions of learning feedback and self-efficacy among college students in different age groups. In contrast, no significant differences were found in learning interaction and higher-order thinking dimensions. Post hoc tests indicated that college students aged 18-19 scored significantly higher on learning feedback compared to those aged 22-23, who in turn scored considerably higher than those aged 20-21; similarly, the group aged 20-21 scored significantly higher than the group aged 24-25. Regarding higher-order thinking, college students aged 18-19 obtained considerably higher scores than those aged 20-21, who achieved significantly higher scores than their counterparts aged 22-23; likewise, the group aged 22-23 outperformed the group aged 24-25.

Table 5
A one-way ANOVA analysis of Major

Dimension	Major				F	P	η2
	Chemistry(*n*=234)	Applied Chemistry(*n*=140)	Environmental Science(*n*=73)	Material chemistry(*n*=14)			
LI	2.510(0.765)	2.407(0.751)	2.611(0.969)	2.457 (0.690)	1.127	0.338	---
LF	3.982 (1.101)	3.832 (1.052)	3.877 (1.194)	4.125 (1.095)	0.740	0.529	---
HOTS	3.468 (0.864)	3.263 (0.771)	3.280 (1.089)	3.456 (0.664)	1.996	0.114	---
LS	3.762 (0.669)	3.623 (0.758)	3.666 (0.789)	3.429 (0.705)	1.825	0.142	---

The findings of a one-way analysis of variance (ANOVA) on the variable Major reveal no statistically significant variations in the four aspects of learning interaction, learning feedback, HOTS, and self-efficacy among students majoring in different areas of chemistry. These findings suggest that the relationship between learning interactions, learning feedback, higher-order thinking, and self-efficacy remains unaffected by the various specializations within the field of chemistry.

Discussion

Significant gender disparities exist in HOTS. Analysis of the data from Table 1 reveals that boys exhibit significantly superior performance to girls in HOTS, albeit with a small effect size. This observation is consistent with the research conducted by Sun et al. (2022)， where male students achieved notably higher average scores than their female counterparts in creative thinking skills, thus corroborating current findings. The gender disparity in critical thinking skills among undergraduate students tends to exhibit a slightly widening trend (Yang & Hong, 2022). The present results align with the higher-order thinking ability of boys compared to girls, as demonstrated in this study.

Furthermore, they support the traditional national cognitive development theory positing that males possess an advantage in normative thinking ability, reflective thinking ability, and logical reasoning ability. However, internationally, Leach Brent reported insignificant gender differences in critical thinking test scores, except for certain subject specialties such as nursing (Leach, 2011). Pascarella and Terenzini identified substantial variations in gender disparities regarding students' value-added critical thinking skills during college, based on the type of institution (Pascarella & Terenzini, 1991). Therefore, the investigation of gender disparities in HOTS not only emphasizes gender parity within the overall sample but also strives for equitable representation across institutions and disciplinary subgroups.

There was a notable gender disparity observed in learning interaction. Kim's study revealed significant differences in the frequency of interactions between students and teachers based on their genders; specifically, female students exhibited a preference for engaging with faculty on an individual basis (e.g., through email or face-to-face communication) rather than participating in public or group settings (e.g., interacting with faculty during lecture sessions) (Kim & Sax, 2009). Regarding faculty contacts related to research, male students exhibited a higher likelihood than their female counterparts to engage in voluntary or paid research assistance for faculty members (Kim & Sax, 2009).

The findings indicate that the overall effectiveness of student engagement in learning interactions within blended learning practices was suboptimal and exhibited significant disparities across two dimensions, namely gender and grade level. This finding is consistent with the observation that student engagement in teacher-student interaction within flipped teaching practice was also considered inadequate overall (Enqin et al., 2016; Zhongmei et al., 2022). For instance, XU's findings indicate that many online learners exhibit low levels of self-regulated learning. At the same time, peer interactions remain superficial and behavioral (Xu et al., 2023). The teacher's selection of learning topics significantly impacts the cognitive structure of learner interaction during online learning. In contrast, self-regulated learning among learners positively influences peer interaction levels (Enqin et al., 2016; Zhongmei et al., 2022).

Kerres and Witt discovered that individuals frequently utilize the Internet for synchronous and asynchronous communication (Kerres & Witt, 2003). For instance, asynchronous communication was encouraged by having students fill out background information surveys, and sociability was facilitated through Facebook (Kerres & Witt, 2003; Köse, 2010). In his research, Overmyer (2014) emphasized the pivotal role of the flipped classroom model in fostering teacher-student interaction, highlighting its potential to enhance learning outcomes and promote student engagement. This study's results contradict previous research suggesting inadequate levels of student engagement in teacher-student interaction within blended learning environments.

The study conducted by Cotten & Wilson (2006) also revealed a lack of overall effectiveness in learning interactions, particularly concerning the limited engagement between students and teachers outside the classroom. These interactions, crucial for collating learning experiences, tend to be brief and primarily focused on specific curriculum-related matters.

The results indicate significant gender differences in learning interactions and HOTS, with boys exhibiting significantly better performance than girls in these dimensions, albeit with a small effect size. Research by H. Kim et al. (2021) lends credence to the idea that there are gender differences in various faculty-student interactions.

Conclusion

Independent sample t-tests were utilized to discern significant gender disparities in HOTS and learning interactions among college students, while no statistically noteworthy differences were observed in learning feedback and self-efficacy. A one-way ANOVA analysis revealed significant differences in the four dimensions of learning interaction, learning feedback, HOTS, and self-efficacy among university students at different academic levels. The study's findings demonstrated how demographic characteristics affected learning variables for students learning advanced mathematics through blended learning, including learning interaction, learning self-efficacy, learning feedback, and HOTS (Abdullah et al., 2017). Further investigation is required to explore the precise mechanisms by which demographic traits impact learning factors and HOTS in blended learning contexts.

This study adds significantly to our understanding of blended learning and the variables affecting students' HOTS. Initially, it was discovered that a major demographic factor affecting students' HOTS was gender. Academic grade level was a key demographic factor influencing students' HOTS and learning characteristics (such as learning interactions, self-efficacy, and feedback). This finding is significant because it raises the possibility that not all students would benefit equally from blended learning and that educators must modify their approaches to better suit the needs of various student bodies. Secondly, this research contributes a more profound knowledge of how demographic features influence learning variables and HOTS in mixed-learning environments. With this information, educators may create blended learning plans that more successfully advance students' learning and development.

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