



OPEN ACCESS

EDITED BY

Chang Liu,
The University of Texas at Austin, United States

REVIEWED BY

JoséEugenio Rodríguez-Fernández,
University of Santiago de Compostela, Spain
Yinghui Shi,
Central China Normal University, China

*CORRESPONDENCE

Lanping Hang
✉ hlphlp@chd.edu.cn

RECEIVED 17 November 2022

ACCEPTED 28 April 2023

PUBLISHED 12 May 2023

CITATION

Zhang Q, Chen SP and Hang L (2023) The influence of interdisciplinary literacy on learning effects among college students: the mediating effects of online physical education on learning behavior. *Front. Educ.* 8:1100764. doi: 10.3389/feduc.2023.1100764

COPYRIGHT

© 2023 Zhang, Chen and Hang. This is an open-access article distributed under the terms of the [Creative Commons Attribution License \(CC BY\)](https://creativecommons.org/licenses/by/4.0/). The use, distribution or reproduction in other forums is permitted, provided the original author(s) and the copyright owner(s) are credited and that the original publication in this journal is cited, in accordance with accepted academic practice. No use, distribution or reproduction is permitted which does not comply with these terms.

The influence of interdisciplinary literacy on learning effects among college students: the mediating effects of online physical education on learning behavior

Qi Zhang¹, Shan Ping Chen² and Lanping Hang^{1*}

¹Department of Physical Education, Chang'an University, Xi'an, China, ²Department of Physical Education, Xi'an Jiaotong University, Xi'an, China

Introduction: The development of high-quality physical education curriculums is required in the information age. Interdisciplinary literacy and student learning behavior are two significant factors that affect the quality of teaching and learning. This study explores the relationship between interdisciplinary literacy (IDL) and learning effects (LE) among Chinese college students during the COVID-19 pandemic, as well as the mediating effects of online physical education learning behaviors (OPELB). This research aims to provide a reference for the development of high-quality online physical education.

Methods: The study involved 691 college students from 10 general universities in Shaanxi Province as research subjects. Descriptive statistics, Pearson correlation analysis, multiple regression analysis and Bootstrap testing were used to evaluate the mediating effects.

Results: There was a significant positive relationship between the three variables of IDL, OPELB, and LE ($p < 0.001$). Multiple regression analysis found that IDL significantly and positively predicted LE and OPELB ($p < 0.001$), and OPELB predicted LE ($p < 0.001$). IDL among college students had a total effect of 0.816 on LE, with OPELB accounting for 22.67% of the mediated effect.

Discussion: This study demonstrates that OPELB has a partial mediating effect on IL and LE, and stable IDL and OPELB improve LE. Therefore, teachers should pay attention to improving students' IDL while encouraging them to develop better OPELB to achieve satisfactory learning outcomes.

KEYWORDS

interdisciplinary literacy, learning behavior, learning effect, mediating effect, physical education

1. Introduction

The Coronavirus disease 2019 (COVID-19) pandemic severely disrupted the pace of education and teaching development. The state issued an emergency notice to “stop classes without stopping teaching; stop classes without stopping learning.” In other words, comprehensive online teaching would be conducted to minimize the negative impacts of the COVID-19 pandemic in terms of delaying the process of university education. A new chapter in higher education was thus opened through comprehensive online teaching. The study of physical

education in the online setting has revealed issues around dissatisfaction among students and a lack of assurance of quality learning effects. Learning evaluations show that when it comes to online learning, students tend to have decreased learning autonomy, decreased physical health, and are more prone to distraction (Xiong and Wu, 2020; Huang et al., 2021). Online physical education expects students to assimilate knowledge and master certain movement-based skills in an information-based environment using human-machine collaboration. Students' online physical education studies should not only emphasize physical literacy but should also include a certain degree of supplemental information literacy. Physical literacy is a special quality and ability specific to the subject of physical education. Physical literacy reflects the core nurturing function of physical education and is the most important ability for students to gradually accept and master through physical education at all stages of schooling. It serves as the foundation for students to develop a lifelong awareness of physical movement, physical behavior, and overall physical health (Ren, 2022).

Physical literacy provides a stable and cohesive intrinsic motivation for students to engage in physical education courses and activities. Information literacy is an important preparatory skill for learners to engage in online learning and relates closely to online learning behavior and learning effects. To properly integrate "internet plus body," students require interdisciplinary literacy which involves gathering information, data, and perspectives around a specific problem from two or more disciplines to achieve a certain outcome and improve learning effects (Committee on Facilitating Interdisciplinary Research, 2004). This paper examines the interdisciplinary combination of information literacy and physical literacy and explores how this interdisciplinary co-education model could effectively enhance learning behavior and outcomes. Previous research (Xiong and Wu, 2020; Xing and Li, 2021) has established that students with poor interdisciplinary literacy experience a significant sense of psychological burden and emotional anxiety, and exhibit problematic learning behaviors when studying online. A student's ability to study physical education online could be indicative of both their learning awareness and learning competence. Interdisciplinary literacy enables students to modulate their learning behavior to achieve satisfactory learning effects. The theory of planned behavior provides a useful account of how online physical education learning behavior can improve the overall quality of online teaching and learning. However, there has been little discussion about the influence of online physical education learning behavior (OPELB) as a mediating variable between interdisciplinary literacy (IDL), and learning effects (LE), and therefore this notion needs further verification. This paper explored the relationship between IDL and LE among Chinese college students during the COVID-19 pandemic, as well as the mediating effects of OPELB. The goal is to provide a reference for the development of high-quality online physical education.

2. Theoretical basis and research hypothesis

With the implementation of 'Information Technology Education 2.0' in 2018, education in China officially entered a new era of the wide-ranging transformation of educational concepts, methods, and resources. Yu (2019) proposed that the boundaries between different educational subjects tend to blur and overlap in the digital environment and that interdisciplinary integration and collaborative research involving

information literacy research is a fast-growing trend. Massive online open courses (MOOCs), teaching involving new forms of media, big data analytics, and artificial intelligence are ways to assist with physical education. The integration of information literacy and interdisciplinary literacy are increasingly important skills for students. Shen and Wu, 2020 found that access to technology and basic internet skills are positively correlated with learning effectiveness and learning satisfaction in the process of online learning; therefore, improving students' information processing and knowledge construction abilities is the key to enhancing students' online learning effectiveness and satisfaction. Chen and Jia (2020) found that students' online learning experience was highly influenced by their proficiency in using online learning platforms. The more proficient students were in using these platforms, the better their online learning experience was. Physical literacy is a necessary competency for students to engage in physical education studies. Physical literacy provides a stable intrinsic motivation for students throughout the learning process to enroll in physical education courses. This guides and supports their future career development. Sun and Zheng (2021) confirmed that an essential core competency is students' ability to effectively manage their learning independently. Research has shown that students with strong core competencies and efficacious learning strategies have significantly improved learning outcomes (Patil et al., 2014, Li and Zhang, 2019). Several studies have highlighted that various factors associated with interdisciplinary literacy are predictive of positive learning effects. This leads us to the first research hypothesis proposed in this paper (H1), namely, that college students' interdisciplinary literacy has a direct positive impact on learning effects.

Alongside the development of information technology and digital learning platforms, online learning is gradually becoming the primary medium for college students to acquire physical education knowledge (Liang, 2019). For students to effectively engage in online learning, the ability to collect and organize digital resources and skillfully use common digital learning platforms is essential (Xing and Li, 2021). Online resources are characteristically abundant, which gives students access to richer and higher-quality informational resources to better meet their learning needs and understand what they have learned. Zhou et al. (2020) showed that the use of multiple digital technologies not only expands and enriches students' capacity for knowledge and information, but also motivates students to create opportunities for independent learning. The ability to effectively navigate the online learning environment triggers active learning as can be seen by analyzing the sequence of students' operating behaviors (Jiang et al., 2018). Physical literacy is a demonstration of competence from the student's point of view. Physical literacy can be defined as the intersection between the student's self-directed physical education learning needs and the actual learning process. A certain degree of intrinsic motivation can facilitate the student's practical physical experiences and more effectively meet their physical education learning needs (Choi et al., 2021). There is a mutual relationship between self-directed learning competency and core literacy which enables students to engage in lifelong learning (Sun and Zheng, 2021). There are significant differences in the distribution of learning behaviors among students of different levels of competence (Wang et al., 2021). More competent students tend to be more active in online learning and have more clearly-defined learning intentions (Schweder, 2019; Wang and Huang, 2020). The above studies show that information literacy and physical literacy have a positive and profound impact on students' learning behavior. Therefore, the second

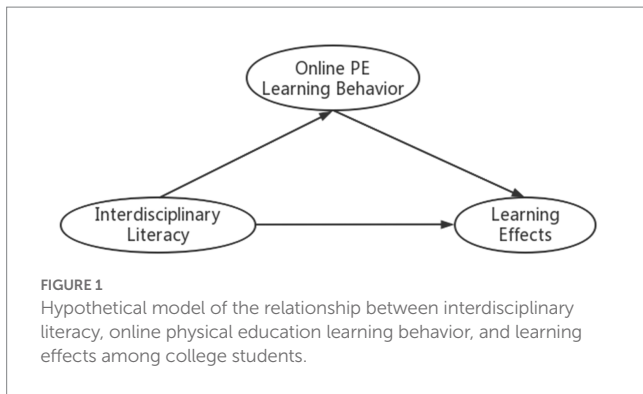


TABLE 1 Variable composition of each scale.

Scale	Variable	Number	Total number
IDL	Information literacy	3	15
	Physical literacy	12	
OPELB	Listening behavior	3	25
	Observation behavior	3	
	Interaction behavior	4	
	Practice behavior	4	
	Demonstrating behavior	3	
	Competition behavior	2	
	Problem behavior	6	
LE	Emotion	1	5
	Knowledge	1	
	Skills	1	
	Fitness	1	
	Grades	1	

hypothesis (H2) proposed in this paper is that college students' interdisciplinary literacy has a direct effect on their online physical education learning behavior.

The COVID-19 pandemic forced physical education to move to fully online teaching and learning. The online learning process necessitates students' independent learning ability, and their online physical education learning behaviors directly affect the effectiveness of their home exercise. Hsiao et al. (2019) found that students' online learning behaviors positively influence long-term learning effects across all groups, and effective online learning behaviors were positively correlated with academic performance. Wang et al. (2021) found that student participation in classroom interactions and discussions significantly increases learning effects and that students' interaction styles significantly influenced their online learning satisfaction (Cai and Li, 2021). Hsu (2019) found that interactive behavior in online courses increases students' enthusiasm to participate in learning and facilitates a meaningful learning cycle and novel learning effects. Li et al. (2020) demonstrated that longer amounts of time spent on practical learning behaviors have significant

positive influences on learning effects among students Miller and Bernacki (2019) found that the degree of students' self-awareness and learning ability effectively increases the formation of subsequent learning behaviors which give rise to improved learning effects. Several lines of evidence suggest that online physical education learning behaviors have a direct impact on learning effects, which brings us to the third hypothesis (H3) proposed in this paper, namely that online physical education learning behaviors mediate the relationship between interdisciplinary literacy and learning effects.

The above hypotheses were used to construct the following model (Figure 1).

3. Methods

3.1. Participants

A stratified random sampling method was used to select college students from 10 universities in Shaanxi province who were not majoring in physical education but who participated in online physical education courses during the COVID-19 pandemic. A total of 80 freshmen, sophomore, and specialist students were sampled from each university for a total sample size of 800, with a 1:1 ratio of male to female students. Questionnaires were distributed using Questionnaire Star. 800 questionnaires were collected of which 109 invalid questionnaires were excluded, totaling 691 valid questionnaires with an efficiency rate of 86.4%. Among the valid questionnaires, 330 (47.8%) were from male students and 361 (52.2%) from female students. The valid questionnaires included 522 (75.5%) freshmen, 142 (20.5%) sophomores, and 27 (4%) specialist students.

3.2. Instruments

3.2.1. Interdisciplinary literacy scale

The questionnaire section on interdisciplinary literacy among college students consists of two components, namely, information literacy and physical literacy. Information literacy involved three question items, namely, college students' proficiency in the use of electronic devices; the operation of digital learning platforms; and the use of digital platforms in general. Physical literacy involved 12 question items that measured students' mastery of knowledge and skills related to physical education as well as their sentiment and willingness to enroll in physical education courses. The interdisciplinary combination of information literacy and physical literacy included a total of 18 question items (see Table 1). A 5 point Likert scale was used for this section, with a score of 1 indicating 'very low compliance' and a score of 5 indicating 'very high compliance'. Higher scores indicated that the participants have better interdisciplinary literacy.

3.2.2. Online physical education learning behavior scale

According to research conducted by Yan (2019), online physical education learning behavior consists of seven aspects, namely, listening, observation, interaction, practice, demonstration, competition, and problematic behavior. In the questionnaire, The 'listening' behavior consisted of three question items, the 'observation'

behavior consisted of three items, the 'interaction' behavior consisted of four items, the 'practice' behavior consisted of four items, the 'demonstration' behavior consisted of three items, the 'competition' behavior consisted of two items, and the 'problematic' behavior consisted of six items (see Table 1). These seven aspects of online physical education learning behavior involved a total of 25 question items. A 5 point Likert scale was used for this section, with a score of 1 representing 'never,' and a score of 5 representing 'always.' Higher scores indicated better performance in online physical education learning behaviors among the participants.

3.2.3. Learning effects scale

Physical education learning effects are evaluated across five aspects (Liu et al., 2017; Hu et al., 2020), namely, physical emotion, physical knowledge, physical skill, physical health, and the subject's performance after participating in online physical education courses during the pandemic. Each aspect involved one question item, for a total of five questions (see Table 1). A 5 point Likert scale was used for this section, with a score of 1 representing 'highly inconspicuous' and a score of 5 representing 'highly conspicuous.' The results were finally analyzed by calculating the mean scores, with higher scores indicating better online physical education learning outcomes among the participants.

3.3. Data collection and analysis

SPSS 26.0 was used to perform descriptive and correlation analyses on the data collected in this study, with the significance level set at $\alpha=0.05$ for all indicators. Since the sociodemographic variables of gender, grade score, and place of residence differed significantly among the study participants, these three variables were included as control variables in the subsequent analysis. Multiple regression analysis was conducted using Model 4 of SPSS PROCESS Macro (version 3.5), as designed by Hayes (2013). The bias-corrected percentile bootstrap method (at 5000 replicate samples) was applied to estimate the 95% confidence intervals (CI) for the testing of the mediating effects. If the 95% CI of the mediating effect did not contain the value 0, this indicated a significant mediating effect (Wen and Ye, 2014). The mediating effects of online physical education learning behaviors between interdisciplinary literacy and learning effects were analyzed while controlling for gender, grade score, and place of residence.

4. Results

4.1. Common method deviation test

This study used self-reporting to collect data which may give rise to common method deviation. Therefore, the Harman one-way test was used to identify potential common method deviation after data collection (Zhou and Long, 2004). The results of the unrotated exploratory factor analysis indicated a total of 12 factors with characteristic roots greater than 1. The maximum factor variance explained by all the components was 31.059% which is lower than the critical criterion of 40%, indicating that the common method deviation was within acceptable limits. Therefore, the self-reporting data collecting this study contained no significant common method deviation.

4.2. Descriptive statistics for each variable

The descriptive statistics for OPELB, IDL, and LE are shown in Table 2. The mean value for the OPELB of college students was 3.86, indicating that college students generally performed well in the online physical education learning process. A small amount of problematic behavior was present, but this was within the controllable range of teacher instruction. The mean value was 3.51 for physical literacy, 4.19 for information literacy, and 3.74 for IDL. This indicates that college students have good digital platform usage skills, but their physical literacy in online physical education courses needs improvement. Overall, there was much room for improvement in terms of IDL. LE are the expectations and results in terms of specific learning, development, and performance criteria. The LE value of the study participants' self-assessments was 3.66, indicating the participants were satisfied with the learning effects that their online physical education courses offered.

Reliability and factor analyses were conducted to evaluate the questionnaire. The Cronbach's α was 0.903 for the IDL section, 0.937 for the OPELB section, and 0.948 for the LE section. The Cronbach's coefficients of the three sections were all greater than 0.9. A Cronbach's coefficient value closer to 1 indicates a higher degree of credibility for each section, and a higher overall quality of the questionnaire.

4.3. Analysis of the mediating effects of online physical education learning behavior

The results of the regression analysis (Table 3 and Figure 2) showed that IDL was a significant positive predictor of LE ($\beta=0.816$, $t=18.165$, $p<0.001$). A regression equation with OPELB as the

TABLE 2 Differences in demographic variables for each variable.

Variable	M (SD)	OPELB	IDL	LE
Listening behavior	4.32 (0.731)			
Observation behavior	3.62 (0.791)			
Interaction behavior	3.42 (0.888)			
Practice behavior	3.99 (0.743)			
Demonstrating behavior	3.68 (0.806)			
Competition behavior	3.58 (0.839)			
Problem behavior	4.41 (0.725)			
OPELB	3.86 (0.595)	1		
Information literacy	4.19 (0.735)			
Physical literacy	3.51 (0.703)			
IDL	3.74 (0.602)	0.564***	1	
Bringing happiness	3.61 (0.957)			
Gain knowledge	3.77 (0.892)			
Acquire skills	3.73 (0.914)			
Enhance physical fitness	3.59 (0.971)			
Improve performance	3.57 (0.989)			
LE	3.66 (0.860)	0.481***	0.562***	1

***Significantly correlated at the 0.001 level (two-sided).

outcome variable, IDL as the independent variable, and gender, grade score, and place of residence as control variables showed that IDL significantly and positively predicted OPEBL ($\beta=0.570$, $t=18.438$, $p<0.001$). After including OPEBL and IDL as independent variables and LE as dependent variables in the equation, OPEBL ($\beta=0.325$, $t=6.004$, $p<0.001$), and IDL ($\beta=0.631$, $t=11.772$, $p<0.001$) both significantly and positively predicted LE.

First, the analysis of the direct effect between IDL and LE (see Table 4) showed that the total effect of IDL on LE was 0.816. The Bootstrap 95% CI had an upper limit of 0.904 and a lower limit of 0.728; the CI did not contain the value 0, indicating that the total effect of IDL on LE was significant. Second, the direct effect of IDL on LE was 0.631 with a Bootstrap 95% CI upper limit of 0.736 and a lower limit of 0.526; the CI did not contain the value 0, indicating a significant direct effect. Finally, the mediating effect value of OPELB in IDL on LE was 0.185, with a Bootstrap 95% CI upper limit of 0.269 and a lower limit of 0.109; the CI did not contain the value 0, indicating a significant mediating effect. Specifically, IDL among college students can enhance OPELB in online learning and thus promote LE. The mediating effect explained 22.67% of the total effect, which indicates that OPELB as a mediator plays a significant role in improving LE in the process of online learning among college students.

5. Discussion

5.1. The advantages of interdisciplinary literacy

Interdisciplinary literacy supports students' online physical education learning process. The results of this study confirm the second hypothesis (H2) of this paper that interdisciplinary literacy among college students has a direct effect on online physical education

learning behavior. The process of online learning requires students to have stable physical abilities, emotions, and excellent information literacy. A high level of interdisciplinary literacy directly supports more effective online learning and more satisfactory learning outcomes. In the new era of deep integration between information technologies and physical education, cultivating students' interdisciplinary literacy is essential for the high-quality development of physical education.

Since the 21st century, the global acceleration of digitization and the rapid development and spread of the internet has made it necessary for students to develop comprehensive interdisciplinary literacy to support the learning process. Interdisciplinary literacy reflects the competence of students across several different aspects and is a significant focus for schools and the state in terms of effective educational development. Nowadays, learning in so-called 'flipped classrooms' requires an adequate level of information literacy Newby (2011). Perez-Stable et al. (2020) have shown that information literacy is necessary for information integration, i.e., the effective use of information technology to retrieve relevant information eventually leads to the integration of knowledge of a given subject, thereby facilitating effective learning. When information technology is integrated into the physical education classroom, it facilitates physical activity factors such as culture, rituals, and traditional values. Furthermore, it facilitates the subjective construction of students' tacit knowledge and a multi-dimensional teaching approach, leading to better teaching and learning experiences for both teachers and students (Yang, 2016). Zhao et al. (2019) and Yu (2017) emphasized the need to accelerate the effective development and evaluation of physical literacy in physical education. Edwards et al. (2017) suggested that physical literacy is both a precursor to physical activity and is developed through physical activity. Research conducted by McGregor et al. (2018) and Longmuir et al. (2017) showed that physical literacy triggers students' motor behaviors which, in turn, positively influenced

TABLE 3 Regression analysis of mediating effects.

Result variables	Predictive variables	<i>b</i>	<i>T</i>	<i>R</i>	<i>R</i> ²	<i>F</i>
OPELB	Gender	0.120	3.204**	0.580	0.337	86.972
	Grade	-0.085	-2.407*			
	Residence	0.016	1.025			
	IDL	0.570	18.438***			
LE	Gender	0.112	2.065*	0.572	0.328	83.586
	Grade	-0.124	-2.428*			
	Residence	0.023	0.990			
	IDL	0.816	18.165***			
LE	Gender	0.073	1.372	0.601	0.361	77.493
	Grade	-0.097	-1.929			
	Residence	0.018	0.779			
	OPELB	0.325	6.004***			
	IDL	0.631	11.772**			

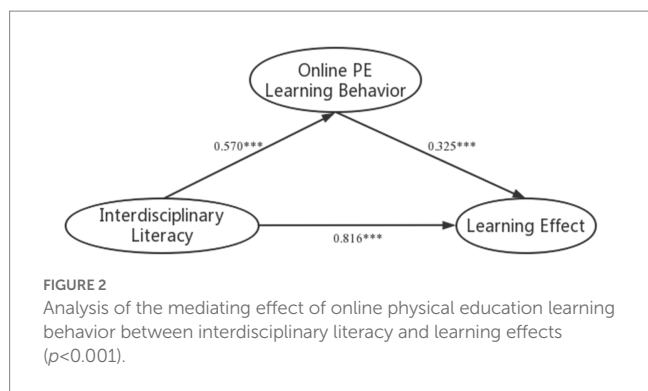


TABLE 4 Analysis of the mediating effect of online sports learning behavior.

	Effect	SE	LLCI	ULCI	Proportion
Total effect	0.816	0.045	0.728	0.904	
Direct effect	0.631	0.054	0.526	0.736	77.33%
Indirect effect	0.185	0.041	0.109	0.269	22.67%

learning effects in physical education courses. Interdisciplinary literacy (involving the use of both information literacy and physical literacy to achieve the purpose of solving certain problems in the online classroom setting) is essential to adapting to learning in modern times and may give rise to new perspectives and new ways of thinking. This study confirms that interdisciplinary literacy is a primary variable that both directly and indirectly triggers certain learning behaviors and learning effects. Therefore, teachers should devote attention to the development of students' interdisciplinary literacy. The highly transferable and sustainable developmental characteristics of interdisciplinary literacy would enable students to integrate various forms of knowledge across multiple disciplines. It is also necessary to improve students' online physical education learning behaviors to achieve satisfactory learning outcomes for both students and teachers.

5.2. The important role of online physical education learning behaviors

Online physical education learning behavior plays a crucial mediating role between students' interdisciplinary literacy and learning effectiveness. The results of this study show a significant positive relationship between interdisciplinary literacy and students' online physical education learning behaviors and learning effects. Further results from the regression analysis and mediating effect analysis revealed an explanatory strength of 22.67% for the mediating effect of interdisciplinary literacy on the learning effects of online physical education learning behaviors. Students' online learning behaviors positively influenced long-term learning effects across all groups. Online learning behaviors were positively correlated with good outcomes and were significant predictors of learning effects. Thus, students' online learning behaviors are critical to achieving positive long-term learning effects. Positive online learning behaviors enable students to achieve more favorable future learning effects and outcomes. In conclusion, online learning behaviors are positively

correlated with learning effects, especially in terms of future learning effects (Hsiao et al., 2019). This is consistent with previous findings and confirms the three research hypotheses (H1, H2, and H3) proposed in this paper. With emerging technologies such as the internet, big data, artificial intelligence, and virtual reality taking the world by storm, modern college students generally have an adequate level of overall information literacy as the new generation of internet users (Wang et al., 2013). They can easily complete various online learning tasks, preparations, operations, virtual classroom interactions, and online searches as required by course instructors. These practical actions all constitute online physical education learning behaviors. Physical education core literacy for college students can be described as students' ability to learn and study the subject independently, i.e., a stable and lasting ability to participate in physical education courses and activities. Schweder (2019) confirmed that students with high degrees of self-control, learning ability, and self-efficacy tend to exhibit better learning behaviors in their studies.

Advances in information technology have given rise to new developmental paths in education. Learning has evolved from the traditional classroom involving direct dialogue with teachers to the online dissemination and exchange of knowledge. Learning styles have become more diversified, technical, and fragmented, and students' learning behavior has transitioned from the teacher-led approach towards a more independent learning approach. The learning process of students engaging in online physical education is dominated by individual learning, with an emphasis on developing independent learning skills and interdisciplinary literacy awareness. Interdisciplinarity is the simultaneous study of multiple disciplines or collaborative participation in a joint effort to solve a particular problem. In the new information environment, the boundaries between different educational subjects tend to blur and overlap, hence collaborative research involving the integration of information literacy research is a major trend (Yu, 2019). Teachers should not only view the improvement of students' interdisciplinary literacy as a key teaching objective but should also pay attention to developing students' metacognitive abilities. They should tailor their teaching to meet the needs of different students and encourage behavioral adjustments to improve interdisciplinary literacy and design interdisciplinary co-education models (Han et al., 2020).

5.3. Limitations and prospects

There are some limitations and shortcomings to this study. First, research involving online physical education learning behaviors among college students is still in the very early stages and a solid theoretical foundation has not yet been formed. Therefore, comprehensive research into the relevant concepts, classifications, and influencing factors is needed in the future to provide a reference for online physical education. Second, this study focused strictly on the mediating role of online physical education learning behavior. Other potential mediating variables such as self-efficacy, motivation, and personality characteristics need to be further explored. Third, a questionnaire involving students' online physical education learning behavior provided the quantitative data analyzed in this study. Students' responses may have been influenced by factors such as their comprehension of the questions, their willingness to answer, and the authenticity of their answers, thus potentially resulting in slight

deviations between the study results and the actual situation. Fourth, since the study was conducted during the COVID-19 pandemic, the applicability of the results in the post-pandemic era needs to be further verified through longitudinal studies. Finally, the study used self-reported measures of variables and thus may be subject to bias. More objective indicators should be included in the future to more accurately measure the research variables.

6. Conclusion

This study explored the mechanisms that influence college students' online physical education learning behaviors in the relationship between interdisciplinary literacy and learning outcomes. The results of the study confirm the first proposed hypothesis (H1) that interdisciplinary literacy among college students positively predicts learning outcomes. Interdisciplinary literacy is a cornerstone of college students' participation in online courses, and a high degree of interdisciplinary literacy can directly contribute towards satisfactory learning outcomes. The results of this study also confirm the second proposed hypothesis (H2) that interdisciplinary literacy among college students positively predicts learning behavior in online physical education. Interdisciplinary literacy supports students' participation in online physical education and motivates them to develop appropriate and effective learning behaviors. In addition, a partial mediating effect of online physical education learning behavior between interdisciplinary literacy and learning effects was confirmed. Specifically, interdisciplinary literacy among college students can enhance their online physical learning behavior and thus promote their online learning effectiveness. In the process of online physical education, students' learning behavior serves as a mediating factor for improving the online learning effect. The above results suggest that stable interdisciplinary literacy and online physical education learning behaviors can lead to better online learning outcomes for college students. Therefore, attention should be paid to improving students' interdisciplinary literacy and encouraging them to develop better online physical education learning behaviors to achieve satisfactory learning outcomes.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

References

- Cai, K., and Li, G. (2021). Satisfaction of physical education majors' online learning of theoretical courses under background of COVID-19 epidemic situation. *Hubei Sports Sci.* 40, 177–183.
- Chen, W. Y., and Jia, W. J. (2020). Research on contributing factors of university students' online learning experience. *J. East China Normal Univ.* 38, 42–53.
- Choi, S. M., Sum, K. W. R., Leung, F. L. E., Wallhead, T., Morgan, K., Milton, D., et al. (2021). Effect of sport education on students' perceived physical literacy, motivation, and physical activity levels in university required physical education: a cluster-randomized trial. *High. Educ.* 81, 1137–1155. doi: 10.1007/s10734-020-00603-5
- Committee on Facilitating Interdisciplinary Research, National Academy of Sciences, National Academy of Engineering, Institute of Medicine. *Facilitating interdisciplinary research*. Washington: The National Academics Press. (2004), 26, pp. 40–110.
- Edwards, L. C., Bryant, A. S., Keegan, R. J., Morgan, K., and Jones, A. M. (2017). Definitions, foundations and associations of physical literacy: a systematic review. *Sports Med.* 47, 113–126. doi: 10.1007/s40279-016-0560-7
- Han, G. L., Zhu, C. S., Cui, J., et al. (2020). The paths of implementation of Australian general in the health and physical education curriculum and universal accomplishment. *J. Phys. Educ.* 27, 111–116.
- Hayes, A. F. *Introduction to mediation, moderation, and conditional process analysis: A regression-based approach*. New York, NY: Guilford Press. (2013).
- Hsiao, C. C., Huang, J. C. H., Huang, A. Y. Q., Lu, O. H. T., Yin, C. J., and Yang, S. J. H. (2019). Exploring the effects of online learning behaviors on short-term and long-term learning outcomes in flipped classrooms. *Interact. Learn. Environ.* 27, 1160–1177. doi: 10.1080/10494820.2018.1522651

Ethics statement

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. The patients/participants provided their written informed consent to participate in this study.

Author contributions

QZ, SC, and LH contributed to the conception and design of the study. QZ performed the data collection, developed evaluation tools, and wrote the manuscript. QZ and SC performed the data analysis. LH provided advice with draft improvement. QZ, SC, and LH revised and significantly contributed to the final version of the manuscript. All authors contributed to the article and approved the submitted version.

Funding

This study was supported by the project of collaborative education between industry and university of the Ministry of Education, with the help of Beijing Foreign Research Online Digital Technology Co., Ltd. Its project number is 220601339172740. The research was carried out with the support of Chang 'An University, which provided convenience for it.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

- Hsu, T.-C. (2019). The different effects of daily-life instant response social media and an educational feedback system on flipped learning: from the evidence of behavioral analysis. *Interact. Learn. Environ.* 18
- Hu, X. Q., Tang, Y., Huang, X., et al. (2020). Research Progress on the effect of physical education learning from the perspective of self-determination motivation theory. *China Sport Sci.* 40, 67–77.
- Huang, R. H., Hu, Y., Liu, M. Y., et al. (2021). Seven facts about online learning—the implications of superscale online education. *Mod. Distance Educ. Res.* 33, 3–11.
- Jiang, B., Gao, M., Chen, Z. H., et al. (2018). Learning process analysis and learning achievement prediction with behavior sequences. *Mod. Dist. Educ. Res.* 02, 103–112.
- Klein, J. T. (2000). A conceptual vocabulary of interdisciplinary science. *Pract. Interdiscip.*, 3–24. doi: 10.3138/9781442678729-003
- Li, K. G., and Zhang, W. H. (2019). Relationship of chemistry learning motivation, learning self-efficacy and academic performance of senior high school students. *Chin. J. Chem. Educ.* 40, 48–55.
- Li, B. P., Zhang, X. R., Chen, Q. Y., et al. (2020). Does fragmental learning have an impact on the learning performance? An experimental research on distributed learning effect in online learning. *Mod. Dist. Educ. Res.* 32, 104–111.
- Liang, J. Y. (2019). Function evolution of university physical education under the background of “big data”. *J. Guangzhou Sport Univ.* 39, 20–24.
- Liu, Y. H., Gong, Q. B., Liang, B., et al. (2017). Experimental research on influence of multivariant evaluation system on students’ sports learning effect. *J. Shandong Sport Univ.* 33, 106–111.
- Longmuir, P. E., Boyer, C., Lloyd, M., Borghese, M. M., Knight, E., Saunders, T. J., et al. (2017). Canadian agility and movement skill assessment (CAMSA): validity, objectivity, and reliability evidence for children 8–12 years of age. *J. Sport Health Sci.* 6, 231–240. doi: 10.1016/j.jshs.2015.11.004
- Mansilla, V. B., and Duraising, E. D. (2007). Targeted assessment of students’ interdisciplinary work: an empirically grounded framework proposed. *J. High. Educ.* 78, 215–237. doi: 10.1080/00221546.2007.11780874
- McGregor, D., Carson, V., Palarea-Albaladejo, J., Dall, P., Tremblay, M., and Chastin, S. (2018). Compositional analysis of the associations between 24-h movement behaviours and health indicators among adults and older adults from the Canadian health measure survey. *Int. J. Environ. Res. Public Health* 15:1779. doi: 10.3390/ijerph15081779
- Miller, C. J., and Bernacki, M. L. (2019). Training preparatory mathematics students to be high ability self-regulators: comparative and case-study analyses of impact on learning behavior and achievement. *High Abil. Stud.* 30:167. doi: 10.1080/13598139.2019.1568829
- O’Connor, L., and Newby, J. (2011). Entering unfamiliar territory. *RUSA Update* 50, 224–229. doi: 10.5860/rusq.50n3.224
- Patil, A. S., Elnaggar, A. C., Kumar, S., Ling, F. W., Stritter, F. T., Temiyakarn, L., et al. (2014). Guided outcomes in learned efficiency model in clinical medical education: a randomized controlled trial of self-regulated learning. *Am. J. Obstet. Gynecol.* 211, 544.e1–e7. doi: 10.1016/j.ajog.2014.05.048
- Perez-Stable, M. A., Arnold, J. M., Guth, L. F., and Vander Meer, P. F. *From service role to partnership: Faculty voices on collaboration with librarians libraries and the academy.* (2020), 20 : 49–72.
- Ren, S. C. (2022). *Research on the cultivation of college students’ healthy behavior from the perspective of Core literacy of physical education* Harbin Normal University.
- Schweder, S. (2019). The role of control strategies, self-efficacy, and learning behavior in self-directed learning. *Int. J. School Educ. Psychol.* 7, 29–41. doi: 10.1080/21683603.2018.1459991
- Shen, Z. H., and Wu, D. G. (2020). A study on the influencing factors of online learning effectiveness and satisfaction of college student: empirical analysis based on structural equation model. *Res. Educ. Dev.* 40, 25–36+59.
- Sun, J. L., and Zheng, C. L. (2021). Current status and trends and enlightenment of international research on self-regulated learning ability. *J. Compar. Educ.* 1, 67–84.
- Wang, G. H., and Fu, G. S. (2021). The influence of knowledge types, presentation methods and learning styles on college students’ online learning—based on the evidence of eye movement. *Mod. Educ. Technol.* 31, 45–54.
- Wang, L. B., Hu, B., Li, J. Y., et al. (2013). State quo survey on information literacy of sports specialized graduate students in Guangdong Province. *J. Guangzhou Sport Univ.* 33, 124–128.
- Wang, S. F., and Huang, R. H. (2020). Research on the mechanism and promotion strategy of online active learning internet. *Open Educ. Res.* 26, 99–110.
- Wang, J., Si, F. S., and Li, H. (2021). Online learning effect evaluation and its influencing factors. *J. Eastern Liaoning Univ.* 28, 224–228.
- Wen, Z. L., and Ye, B. J. (2014). Mediated effects analysis: methods and model development. *Adv. Psychol. Sci.* 22, 731–745. doi: 10.3724/SPJ.1042.2014.00731
- Wen, Z., and Ye, B. (2014). Analyses of mediating effects: the development of methods and models. *Adv. Psychol. Sci.* 22, 731–745. doi: 10.3724/SPJ.1042.2014.00731
- Xing, X. S., and Li, J. (2021). The new ideas for the development of online education in the “internet+” era. *China Educ. Tech.* 5, 57–62.
- Xiong, Y. J., and Wu, Q. S. (2020). A survey on secondary school students’ satisfaction with online learning in the context of “stopping classes and not stopping learning”—an analysis based on a survey of 27,199 secondary school students. *Chin. Vocat. Tech. Educ.* 29, 40–48.
- Yan, Z. J. (2019). *Construction of observation index system of high school students PE Class Learning Behavior.* Bei Jing Sport University.
- Yang, W. X. (2016). On the shifting of China’s contemporary school physical education reform value orientation—from fitness enhancement to comprehensive development. *J. Phys. Educ.* 23, 1–6.
- Yu, S. M. (2017). Key and effective strategies that should be grasped for the cultivation of students’ physical education disciplinary Core attainments. *J. Phys. Educ.* 24, 84–88.
- Yu, Y. (2019). Information literacy education transformation under the new information environment based on an interdisciplinary perspective. *Res. Libr. Sci.* 9, 10–16+66.
- Zhao, F. X., Wang, Y. T., and Wang, M. C. (2019). Research Progress and inspiration of key literacy of PE Discipline. *J. Beijing Sport Univ.* 42, 128–137.
- Zhou, H., and Long, L. (2004). Statistical remedies for common method biases. *Adv. Psychol. Sci.* 12, 942–950.
- Zhou, G. H., Wu, P. R., and Zhao, X. (2020). Opportunities, challenges and trends of basic education reform in era of education information 2.0. *J. Teach. Manag.* 33, 13–16.