Influencing Factors of Learners' Cognitive Engagement in an Online Learning Environment

A PST Model

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Abstract—This study used the Pedagogical Affordance-Social Affordance-Technical Affordance (PST) model as basis in designing a questionnaire to investigate the influencing factors of learners' cognitive engagement in an online learning environment. Moreover, the influencing degrees of educational, social, and technological affordances on learners' cognitive engagement in an online learning environment were estimated. Research results demonstrated that the overall Cronbach's α of the questionnaire was 0.883, KMO was 0.859, and cumulative variance interpretation rate after rotation was 79.199%. Thus, the designed questionnaire has very good reliability and validity. Educational affordance can significantly improve learners' superficial and deep learning engagements. Social and technological affordances can significantly increase learners' superficial learning engagement, but they cannot significantly increase deep learning engagement. Online learning contact time has significant differences under the 1% and 10% levels. Research results can provide some references to explore the relationship between the PST model and cognitive engagement and improve the overall affordance of an online learning environment.

Keywords—online learning environment, learners, cognitive engagement, PST model, technological affordance, educational affordance

1 Introduction

In the "Internet + education" era, the integration degree of information technology and education is increasing continuously. The influence of the COVID-19 pandemic has prompted China to comprehensively implement large-scale online teaching mode, shifting from the traditional classroom teaching mode centered on the teaching activities of teachers to the independent online learning centered on learners. In existing teaching scenes, there are increasing categories of information technologies and considerably diversified methods. Technological intervention and technological-enriched

environment have become an inevitable learning development trend. At present, integration with information technologies, such as could computing, big data, Internet of Things (IoT), and artificial intelligence, has reconstructed new states of different industries and further promoted the application of technologies in education. Applications of technologies in the education ecology promote the transformation of educational concepts and innovation of teaching modes. With the enriching degree of technologies and continuous improvement of intelligence degree, digitalization, electronization, and hardware in a classroom learning environment will become ordinate states in the future. Flipped classroom and smart education based on the cloud platform, microlectures, and mobile terminals have been widely applied in classroom environment teaching. In recent years, the gradual penetration of technologies in the education field has demonstrated that teaching in a technology-rich environment can significantly promote student engagement. Adverse effects of negative factors (e.g., distraction, unsatisfying learning outcome) on learner engagement can be relieved significantly by enhancing the online learning environment.

Given that online learning lacks face-to-face communication between teachers and students and has a weak sense of immediacy, learning engagement of learners to online learning is not satisfying in China. During online teaching classes, some students appear to be engaged in e online learning, but they neither enter into deep learning nor adopt corresponding learning strategies. This situation has immense hidden dangers to students' individual development and also has significant influences on the overall teaching effect. The learning state of learners is difficult to determine in a timely manner and real engagement state is challenging to master because online learning characterized by autonomy, self-assistance, and convenience. The quality of online learning outcomes is typically related directly with the quality of students' course mastery. Learning engagement is a major prediction index of the learning performances of students and an important reference element to the quality of school education. Numerous studies have demonstrated that the learning engagement of university students is beneficial to improving their lifelong learning ability, facilitating their considerable progresses in higher-order thinking abilities, and encouraging them to turn in good academic performances. On the one hand, high-level learning engagement can motivate learners to comprehensively realize self-regulation, self-management, and self-promotion, and increase self-efficacy. On the other hand, such an engagement can strengthen high-order thinking abilities, thereby enabling students to realize effective deep learning. High-efficiency and accurate improvement of learning engagement of university students to online learning is an essential requirement of China's higher education in the current background of the COVID-19 pandemic. Lastly, such an enhancement is also an important influencing factor in improving online learning performances.

2 Theoretical basis and hypotheses development

2.1 Theoretical basis

Astin, A. W. [1] proposed student involvement theory and advocated the important role of "involvement" in the learning process of students. Physiological and psychological engagements to learning process are important elements of student

involvement. Student involvement theory emphasizes that the primary mission of higher education is to set a learning environment that encourages the positive involvement of students, promotes their cognitive development, and results in high-efficiency learning achievements. The major opinion of this theory is that learning engagement refers to the effort and physical power that students input to form learning experiences. Learning engagement is a continuous process, and different students may show different degrees of engagement state. In a specific context, the same students show different degrees of engagement to different tasks and at different times. Degree of engagement can be measured comprehensively in terms of quality and quantity. The acquired learning and development of students from the education process are directly related with their engagement. Implementation effects of education policies are determined by their degree of learning engagement. Therefore, student involvement theory was the basis of the basic theory for questionnaire design in this study.

2.2 Hypotheses development

With the continuous integration of information technologies in the curricula, the role of such technologies in educational teaching has become increasingly prominent. However, apart from promoting teaching, technologies also bring instability in online teaching quality. One important reason is that the components of an online learning environment are extremely complicated and have important influences on cognitive engagement. Many studies have discussed the influencing factors of cognitive engagement in an online learning environment. Richardson, J. C., et al. [2] explained that with the increasing acquired experiences in online learning, students have assumed more responsibilities for their studies. Research conclusions have indicated positive influences on how online courses and designers organize online courses. Greene, B. A., et al. [3] found that perception is positively related with significant cognition and that learning objective is positively related with perception ability. DeBacker, T. K., et al. [4] determined that achievement objectives, which are set by learners, may influence their cognitive engagement. Taylor, B. M., et al. [5] demonstrated that good teaching methods of teachers (e.g., representation, guidance) could improve learners' higher-order thinking. These methods could comprehensively promote the reading growth of students and improve their cognitive engagement in literacy learning to the maximum extent. Zhu, E. [6] determined that teacher–student interaction has important influences on students' cognitive engagement. Ben-Eliyahu, A., et al. [7] discovered that self-efficacy is positively related with overall involvement and the objective orientation of performance method is positively related with behavioral cognitive engagement. Park, S., et al. [8] believed that motivation support is a key factor that determines the successful online distance learning experiences of university students. The results demonstrated that teachers, tutors, and designers of online courses attach considerable attention to the motivation characteristics of students; and they are major influencing factors of students' cognitive engagement. Chang, Y., et al. [9] explained that self-efficacy and peer support perception have significantly positive influences on cognitive engagement. Autonomous motivation can mediate the influences of peer support perception on cognitive engagement. Walker, C. O., et al. [10] deemed that self-efficacy, internal motivation, and academic identity are three major influencing aspects of

cognitive engagement. Mallawaarachchi, V., et al. [11] presented the successful use of such a learner support tool, and developed to be used in bioinformatics teaching and research. Tang, C. M., et al. [12] demonstrated that good digital literacy is the prerequisite for students to achieve effective learning in a blended learning environment. Shamatha, J. H., et al. [13] found that when classroom activities are guided by components of an effective learning environment, students are likely to develop context and transferable understanding. Gonzalez, G. R., et al. [14] believed that success in a learning-oriented educational concept in the marketing curriculum is determined by creating an effective learning environment. Consequently, creating an effective learning environment is conducive to improving the academic performance level of learners. Delialioglu, O., et al. [15] demonstrated that real interactive learning activities, team cooperation, and personalized learning of students play important roles in blended learning courses. Preciado-Babb, A. P., et al. [16] believed that students' use of mobile technologies could significantly improve their learning engagement. Schols, M. [17] found four factors that encourage teachers and educators to participate in technological learning. Yan, Y., et al. [18] indicated that cognitive engagement of learners can be promoted through game-based teaching mode.

Kirschner, P., et al. [19] proposed a relatively classical PST model. He was convinced that a technically supported effective learning environment will be equipped with educational, social, and technological affordances. Educational affordance refers to the characteristic of a learning environment or technical tools that determines whether a learning activity can be implemented or how to be implemented in a given educational context. Social affordance is a characteristic that the learning environment perceived by learners or technical tools can promote the social interaction of students. Technological affordance refers to the usability of a learning environment or technical tools. Therefore, online learning environment was expressed by educational, social, and technological affordances in this study. Accordingly, the influences of the three affordances on learning engagements, including superficial and deep learning engagements, were analyzed.

Hence, the following hypotheses were proposed:

H1: In online learning, educational affordance can significantly improve learners' superficial learning engagement.
H2: In online learning, social affordance can significantly improve learners' superficial learning engagement.
H3: In online learning, technological affordance can significantly improve learners' superficial learning engagement.
H4: In online learning, educational affordance can significantly improve learners' deep learning engagement.
H5: In online learning, social affordance can significantly improve learners' deep learning engagement.
H6: In online learning, technological affordance can significantly improve learners' deep learning engagement.

3 Methodology

3.1 Questionnaire design

A questionnaire of *Influencing Factors of Learner's Cognitive Engagement in the Online Learning Environment* was designed. It covers the following two aspects. Part I covers four questions on gender, subject, postgraduate grade, and online learning contact time. Part II is the core part of the questionnaire. Given that cognitive engagement of learners in an online learning environment involves relatively complicated influencing factors, the literature review and Kirschner, P., et al. [19] indicated that a technically supported effective learning environment is equipped with educational, social, and technological affordances. The three aspects were measured by four, five, and four questions, respectively. Cognitive engagement includes deep and superficial engagements, which were measured by three questions in the questionnaire of Greene, B. A., et al. [20]. All problems used a seven-point Likert scale.

3.2 Respondents

This study initially completed a pre-survey in the school of the author. The questionnaire was corrected and enhanced according to feedback information, and evaluated by inviting experts in the education technology field. Eventually, the formal questionnaire was formed. Postgraduate students in a university in Zhengzhou City, Henan Province were investigated using the formal questionnaire. This university has invested considerable capital for teachers' special online teaching training since the start of the COVID-19 pandemic, thereby improving their online teaching abilities. Moreover, the university purchased an online teaching platform that enables teachers to use several online teaching modes, such as live and recorded broadcasting. To acquire effective survey data in a limited time range, the questionnaire was formulated on the website of www.wjx.cn, which is an extensively used online investigation tool in China, and a QR code was generated. The questionnaire was mainly sent through the working WeChat group of faculty members in postgraduate school. Course teachers transferred it to all postgraduate students in the university. A total of 235 questionnaires were collected, among which 185 valid ones were collected after questionnaires with missing information and the same answers to all questions were excluded. Effective collection rate was 78.72%. Basic information of the respondents are as follows. For gender, there were 100 males (54.05%) and 85 females (45.95%). For subject, there were 33 from Engineering Science (17.84%), 35 from Science (18.92%), 74 from Economics (40%), and 43 from Management Science (23.24%). For postgraduate grades, there were 49 first-year graduate students (26.49%), 80 second-year graduate students (43.24%), and 56 third-year graduate students (30.27%). For online learning contact time, there were 15 students who have engaged in online learning for under 0.5 year (8.11%), 8 students for 0.5–1 year (4.32%), 29 students for 1–2 years (15.68%), 42 students for 2–3 years (22.7%), and 91 students for over 3 years (49.19%). Evidently, gender ratio was relatively balanced. Given that the university emphasizes on economic management, the proportions of Economics and Management Science were relatively high. Grade distribution of postgraduate students was relatively reasonable. Given that

postgraduate students were chosen as respondents, nearly 50% of them have engaged in online learning for over 3 years, indicating that they have very good online learning experiences.

4 Results analysis and discussion

4.1 Reliability and validity test

Reliability refers to the stability and consistency of questionnaire survey results when using the same method to the same respondents. That is, reliability reflects whether a measuring tool can accurately measure the tested object or variable accurately. Higher reliability indicates that the scale is more stable. This study applied Cronbach's α in the reliability test. Results are shown in Table 1.

Table 1. Reliability test results

Variable Types	Names of Variables	Codes of Questions	Cronbach's α	Cronbach's α
Independent variables	Educational affordance	A1–A4	0.880	0.883
	Social affordance	B1–B5	0.909	
	Technological affordance	C1–C4	0.900	
Dependent variables	Superficial learning engagement	Y1-1–Y1-3	0.928	
	Deep learning engagement	Y2-1–Y2-3	0.749	

Reliability of the collected data was tested using SPSS25.0. Evidently, Cronbach's α of specific variables is above 0.7 and the overall Cronbach's α is 0.883 (>0.8). This result indicates that research data has very high reliability quality and the questionnaire has good quality. Moreover, the result interprets comprehensively that the designed online learning questionnaire has very good reliability and can be used for further deep analysis.

Validity, or known as effectiveness, expresses the degree that measurement results of questions in the questionnaire can accurately reflect response contents. Higher validity indicates a higher agreement between the measuring results and corresponding investigation contents. Structural validity test on this study's data was performed using SPSS25.0. Structural validity refers to the relationship between the structure reflected by the measuring results and measuring values. The structural validity of a questionnaire is often expressed by factor analysis results. Results are shown in Tables 2 and 3.

Table 2. Validity test results

KMO value		0.855
Bartlett sphericity test	Approximate chi-square	2711.460
	df	171
	P value	0.000

Table 2 shows that the KMO value is 0.859 and the corresponding *P* value is 0.000 (<0.01). This result indicates that the collected questionnaire survey data are very appropriate for factor analysis.

Table 3. Factor analysis results

No. of Questions	**Initial Eigenvalues**			**Extracted Quadratic Sum**		
	Total	**Variation %**	**Accumulation %**	**Total**	**Variation %**	**Accumultion %**
A2	4.026	21.189	54.227	4.026	21.189	54.227
A3	2.441	12.846	67.073	2.441	12.846	67.073
A4	1.19	6.261	73.334	1.19	6.261	73.334
B1	1.114	5.865	79.199	1.114	5.865	79.199
B2	0.595	3.133	82.332			
B3	0.525	2.764	85.096			
B4	0.509	2.677	87.773			
B5	0.382	2.012	89.785			
C1	0.319	1.679	91.464			
C2	0.253	1.333	92.797			
C3	0.239	1.258	94.055			
C4	0.217	1.141	95.197			
Y1-1	0.191	1.007	96.204			
Y1-2	0.179	0.941	97.144			
Y1-3	0.172	0.905	98.049			
Y2-1	0.154	0.809	98.858			
Y2-2	0.119	0.628	99.486			
Y2-3	0.098	0.514	100			

Table 3 shows that the cumulative variance interpretation rate after rotation is 79.199%, which is considerably above 50%. This result reveals that the research items involving influencing factors could be extracted effectively.

4.2 Linear regression

Table 4. Regression results of the influencing factors of superficial learning engagement

Variables	Regression Coefficients	Standard Deviation	T-Values
Constants	3.4235***	0.5337	6.41
Educational affordance	0.2258*	0.1166	1.94
Social affordance	0.2410***	0.0869	2.78
Technological affordance	0.2148**	0.0950	2.26

Note: ***, **, * indicate significance at 1% level, 5% level, and 10% level, respectively.

Table 5. Regression results of the influencing factors of deep learning engagement

Variables	Regression Coefficients	Standard Deviation	T-Values
Constants	3.6170***	0.4837	7.48
Educational affordance	0.2219**	0.1057	2.10
Social affordance	0.1278	0.0788	1.62
Technological affordance	0.1289	0.0861	1.50

Note: ***, **, * indicate significance at 1% level, 5% level, and 10% level, respectively.

Tables 4 and 5 show the following results.

(1) H1 is true: In online learning, educational affordance can significantly improve learners' superficial learning engagement. The reasons are explained as follows. For educational affordance, teachers realize teaching objectives comprehensively by proficiently using methods more appropriate for online learning. At present, teacher groups from universities have relatively high information literacy and they are familiar with online teaching. In a specific online teaching environment, they can complete a specific teaching process effectively. In online teaching activities, they can realize the full teaching process by using various teaching tools based on information communication and appropriate teaching methods for online learning. For example, teachers use case discussion, team cooperation learning, inquiry-based learning, and role play during online learning. These methods can significantly improve learners' internal motivation, encourage them to enhance their learning motivation, and increase their superficial learning engagement.

(2) H2 is true. In online learning, social affordance can significantly improve learners' superficial learning engagement. Given that learners have different cultural and education backgrounds in an online learning environment, they are encouraged to communicate with teachers and peers when encountering problems and present strong demands for platform use and online emotional communication. Online learning platforms can completely support synchronous or heterogeneous communications through interaction affordance of information communication tools, as well as strengthen peer-peer interactions and student-teacher interactions. Moreover, online learners can

interact mutually through information sharing, team cooperation, problem discussion, and theme lecture. Teachers play an important role in these learning processes, specifically by guiding and managing the learning activities of students.

(3) H3 is true. In online learning, technological affordance can significantly improve learners' superficial learning engagement. The reasons are explained as follows. With the continuous development of education informatization, technological affordance plays an irreplaceable role in the construction of an information teaching environment. Only good technological affordance can build a good environment for learners and teachers, thereby enabling the smooth promotion of teaching activities. At present, technological affordance of most online learning platforms is characterized for easy learning, simple structure, and convenience. In teaching activities, most online learning platforms allow learners to upload or download learning resources in various forms, showing strong compatibility and high sharing degree of network resources. Meanwhile, various interfaces of online learning have excellent visual sense and strong attraction, which are easily accepted and used proficiently by learners. Online learning platforms are easy and convenient, thereby enhancing the interest of learners in these platforms. Therefore, superficial engagement of learners is relatively evident.

(4) H4 is true. In online learning, educational affordance can significantly improve learners' deep learning engagement. In the knowledge construction process, learners can share personal information and publish their own opinions through the online interaction link, thereby further solidifying knowledge. Students can also use knowledge MindMap to construct a knowledge system by connecting key knowledge points. In solving a specific problem, teachers can present the problem through various videos or short films on the online platform. Students discuss the problem by searching information on the Internet and using communication tools. Teachers design and implement various effective teaching methods by using information tools to enhance interest on knowledge and encourage students to pursue diversified learning activities. With respect to the learning objective, online learning platforms can support various learning activities. Moreover, information tools can enrich knowledge, make knowledge visual, and enhance the learning interest of students, thereby helping them considerably comprehend deep knowledge.

(5) H5 is false. In online learning, social affordance cannot significantly improve learners' deep learning engagement. This result can be explained as follows. Although an increasing number of online learning platforms provide free and full communication environment for learners, social affordance reflects the information communication ability between learners and teachers and between different learners. However, there is no face-to-face communication between students and teachers and among different students in an online learning environment. Hence, there is no sense of immediacy. Consequently, deep engagements, such as free discussion, complicated problem solving model, higher-order thinking ability training, and operation skill internalization, are not enhanced significantly.

(6) H6 is false. In online learning, technological affordance cannot significantly improve learners' deep learning engagement. Although technological affordance can promote learners' deep learning engagement, the regression coefficient is not significant. This outcome can be interpreted as follows. Regions with strong technological affordance can realize synchronous or heterogeneous communication, enhance

emotional communication among learners, and provide strong technological support to various types of network teaching interaction. However, after learners become familiar with such a learning mode, their interest wanes and their curiosity for this interaction mode loses gradually with the passage of time. Consequently, the possibility for deep reflection based on good platforms decreases. Moreover, deep learning proposes a high requirement on learners' self-study. Learners have to spend some time in higher-order thinking mode, such as reflection and exploration of solving complicated problems, which mainly relies on knowledge accumulation and experiences of learners.

4.3 Difference analysis

Table 6. Differences in influences of online learning contact time on superficial and deep learning engagements

Learning Engagement Types	Online Learning Contact Time (mean ± standard deviation)					*F*	*P*
	1.0 (n = 15)	2.0 (n = 8)	3.0 (n = 29)	4.0 (n = 42)	5.0 (n = 91)		
Superficial engagement	3.82±1.12	5.63±1.07	4.63±1.37	4.44±1.18	4.35±1.03	3.676	0.007***
Deep engagement	4.57±0.97	5.06±1.06	4.43±0.81	4.22±0.88	4.87±0.79	2.187	0.072*

Note: ***, **, * indicate significance at 1% level, 5% level, and 10% level, respectively.

Table 6 shows that influences of online learning contact time on superficial learning engagement have evident differences at the 1% level. Learners who engage in online learning for 0.5–1 year show the highest superficial learning engagement. The reason is that they need some time to be familiar with online learning mode in the beginning, but they will be more familiar with it after half a year, thereby increasing superficial learning engagement to the evident peak. After 1 year of engagement, learners may master online learning skills better and they may choose on-hook, finding someone to study for them, and other misuses. All of these factors can decrease learners' superficial learning engagement annually. This conclusion also inspires universities to focus substantially on the problem that learners are easily bored with online learning and emphasize on curriculum resources development and emotional communication during online teaching to maintain learners' superficial learning engagement at a high level for a long period.

Influences of online learning contact time on deep learning engagement have evident differences at under the 10% level. Deep learning engagement of learners reaches the peak after engaging in online learning for 0.5–1 year, showing the same variation characteristics with superficial learning engagement. As online learning contact time exceeds 3 years, learners' deep learning engagement increases again owing to the following reasons. Deep learning engagement mainly comes from learners' endogenous motivation. After they gain familiarity with the online learning mode, they can exert considerable effort and time to reflect on deep problems, deep interaction with teachers, and reflection on higher-order thinking problems. Therefore, their deep engagement is increased

significantly. This conclusion also inspires online course teachers to provide some challenging learning resources to students who are good at online learning and provide students who have engaged in online learning for over 3 years additional learning contents for reflection, team cooperation, group discussion, and free development. Moreover, teachers will formulate more personalized teaching schemes for students to maintain a high-level of deep engagement.

5 Conclusions

Information technologies, such as big data and IoT, facilitate the enhancement of an online learning environment. Online learning has become one of the learning modes are accepted by learners. Strong education informatization technological intervention and technology-rich environment enrich the teaching environment. The PST model is used as basis to estimate the influencing degrees of educational, social, and technological affordances of an online learning environment on learners' cognitive engagement. Research results indicate that the overall Cronbach's α, KMO value, and cumulative variance interpretation rate after rotation are 0.883, 0.859, and 79.199%, respectively. This result proves that the designed questionnaire has very good reliability and validity. Educational affordance can significantly increase learners' superficial and deep learning engagements. Social and technological affordances can significantly increase learners' superficial learning engagement but cannot significantly increase deep learning engagement. Influences of online learning contact time on superficial and deep learning engagements show significant differences at the 1% and 10% levels. Centered at social sampling in a more extensive scope, further deep studies of the influences of other independent or mediating variables on cognitive engagement of learners are needed in the future.

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