Comparing the Effects of SPOC and Face-to-Face Courses and Factors Influencing the Effects

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***Abstract*—Distance education has been widely used in universities due to the outbreak of Covid-19. SPOCs (Small Private Online Courses) have high enrollment and completion rates in higher education due to their ability to provide students with personalized deep learning. This study aims to investigate the learning effect of SPOCs and further explores the reasons that affect its effectiveness. The study found that: a) there is a certain difference in the learning effect between SPOCs and face-to-face courses; b) the learning effect in SPOCs can be effectively improved by enhancing the interest in learning, and c) the teacher's internal and external assistance can significantly improve the learning effect. The study suggested that the "Hard-Pure" SPOCs needs more detailed course design, enhancing students' motivations and learning interests in SPOC courses, and strengthening teachers' assistance to students in and out of class.**

***Index Terms*—Distance education, SPOCs, Biglan model, learning effects, face-to-face.**

I. Introduction

With the continuous development of information technology, distance education in universities has become a common way of learning all over the world. Based on the 14th annual report of the state of online learning in U.S. higher education conducted by the Babson Survey Research Group and the Online Learning Consortium in 2018, total distance enrollments are composed of 3,003,080 students taking exclusively distance courses, and 3,356,041 students who are taking a combination of distance and face-to-face courses. Due to the COVID-19 pandemic, face-to-face courses in most of educational institutes have shifted to online courses [1], and it could permanently change how education is delivered in the post-COVID era [2].

Although online teaching has been widely used, the learning effect of comparing various teaching modes has not been extensively studied [3]. In addition, many studies fail to compare and contrast online learning in different types of courses [4]. In some colleges and universities, some theoretical courses in science and engineering have launched online courses, such as the biological conductor course at Harvard University, and the algorithm course at Stanford University. For some teachers who have long been accustomed to the face-to-face teaching mode, online teaching has brought new challenges to their teaching [5], [6], such as the application of online teaching methods and the use of online teaching environment [7], which may influence the students' performances [8]. Therefore, the current study explores the learning effectiveness of SPOCs in undergraduate science and engineering theoretical courses, and we further explore the factors of the internal learning environment that affect students' learning effectiveness with the goal of proposing improvement strategies for the teaching design and implementation of SPOCs.

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II. Background

A. Studies on the Learning Effectiveness of SPOCs

SPOC is a small-scale restricted online course, a form of online education. Compared with MOOCs, SPOCs are characterized by a smaller number of students, an emphasis on blended learning, an ability for the teachers to teach and assist students throughout the course, and the advantages of high learners' interactions and learners' completion [9]. Thus, scholars believe that SPOCs are suitable for undergraduate education [10], [11]. Many researchers have explored the effectiveness of SPOCs from different perspectives [12]-[14]. For example, a study pointed out that SPOCs can promote teacher-student interactions in online classes and further promote deep learning [10]. A meta-analysis investigated the effectiveness of SPOCs including courses in computer sciences, English, Physics, and so forth; the results show that, compared with face-to-face courses, SPOCs can not only improve students' academic performance, knowledge comprehension, and application ability but also improve their abilities in self-study and self-management. Moreover, SPOCs can stimulate learning interest, improve seriousness, and promote learning participation [15]. However, the effectiveness of SPOCs in universities is still controversial. In a study of the effectiveness of SPOCs, 76.43% of college students believed that they could master 40%-80% of the knowledge, and only 22.36% of the students mastered more than 80% of the knowledge [16]. Other empirical research also points out that the learning effectiveness of SPOCs in universities is lower than that of face-to-face courses [17]-[19].

B. Course Categories and Online Learning Effectiveness

Many scholars have pointed out that when exploring the effectiveness of online learning, it is necessary to consider the impact of different disciplines and different course

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categories on the effectiveness of online learning [4], [20]. Some scholars have explored the learning effectiveness of the SPOC mode for specific courses [21], [22]. For example, Jia and Zhang [18] explored the learning effectiveness of SPOCs in analog circuit courses. Compared to face-to-face courses, SPOCs not only more effectively improve students' comprehensive circuit application ability, but also enhance students' interest in learning. This study points out that SPOCs can also be applied to related courses such as "Signals and Systems" and "Digital Signal Processing". Karr *et al.* [23] points out that the online engineering mathematics course has a good teaching effect on college students, and the research of Stuckey-Mickell [24] shows that the visualization function of online courses can improve the learning effect of undergraduate biology courses, Njoku's [11] study focuses on the online learning effect of health courses, and the research conclusion shows that online health courses contribute to the learning effect of undergraduates.

C. The Biglan Model and Research Gaps

Biglan classified university courses in his 1973 study, arguing that there are three main differences between different disciplines: a) the existence of a single paradigm, b) a focus on practical application, and c) focus on living systems [25]. And thus the university courses are divided into four subject categories, namely "Hard-Pure", "Hard-Applied", "Soft-Pure", and "Soft-Applied". "Hard-Pure" includes the theoretical courses of science and engineering, such as chemistry, mathematics, physics, microbiology, etc. "Hard-Applied" includes science and engineering applied courses, such as computer science, mechanical engineering, agricultural economics, engineering, etc.; "Soft-Pure" includes the theoretical courses of humanities and social sciences, such as English, history, anthropology, philosophy, etc.; "Soft-Applied" includes the applied courses of humanities and social sciences, such as business accounting, finance, education, and business management, etc. The Biglan classification has subsequently been widely used and validated in various fields [26]-[28].

Although the studies mentioned above provide a reference for exploring the learning effect of SPOCs in universities, there are still gaps for further exploration in the research. Existing studies have compared the academic performance of SPOCs and face-to-face courses, but few studies consider the impact of differences in course categories on the learning outcomes of SPOCs. Therefore, based on the Biglan model, exploring the SPOCs teaching effect of a category has certain practical and theoretical value for teaching and online education research in universities.

III. Research Design

A. Context of the Study and Research Questions

This study collected data from a large public university. This university has four campuses. This study sought to address a local issue at the large public university: due to the mutual recognition and transfer of credits among different campuses, the undergraduate education of this university has promoted the development of SPOCs to ensure that the students can choose courses freely among the four campuses. The university attaches great importance to the quality of undergraduate online education, and each teacher must pass a semester of "online teacher training" courses and obtain an "online teaching qualification certificate" to teach online. The teaching team of each course prepares and adopts unified teaching content. Most undergraduate courses offer both face-to-face courses and SPOCs on the LMS platform. For example, undergraduate statistics courses have five face-to-face courses and two SPOCs.

Since few schools offer parallel classes of face-to-face courses and SPOCs for the same course, there is a lack of research to compare the learning outcomes of SPOCs and face-to-face courses for students in undergraduate "Hard-Pure" courses. Learning effectiveness and learners' evaluation of courses are important factors that reflect the quality of teaching. Therefore, this study raises the following questions:

1) In the undergraduate "Hard-Pure" courses, is there any difference in the performance of students in SPOC courses and face-to-face courses?
2) From the perspective of the internal learning environment (the design and implementation of SPOCs), what factors affect the learning effectiveness of SPOCs?

B. Data Sources

Grades: the university adopts the face-to-face teaching mode (=1) and the SPOC teaching mode (=2). According to the school's regulations, SPOCs and face-to-face courses of the same course use the same assessment methods. Semester academic final grades include exam grades, attendance rate, class participation, and daily homework grades. The course grades are given by the teacher after a comprehensive calculation at the end of the semester. The collected data includes the grades of freshman to senior year students. The school requires a unified use of grades 0-4 for the semester, corresponding to fail, pass, medium, good, and excellent.

Course Evaluations: the LMS platform sends students a link to an encrypted questionnaire at the end of the semester and informs students that the system protects student privacy to ensure students can answer honestly. The questionnaire is designed by the university's teaching and learning center. The questionnaire is divided into eight questions, which mainly ask students to evaluate the internal factors of the learning environment in the four dimensions of the complex dynamic system model of computer-mediated teaching [29]. As shown in Table I, the course evaluation questionnaire adopts the Likert five-point scale ranging from excellent to poor. The questionnaire has good reliability and validity: Cronbach's alpha coefficient is 0.988, and the criterion correlation coefficient $r = 0.194$, $p < 0.01$.

TABLE I: Course Evaluation Questionnaire

E1	Teaching objectives and coursework.
E2	The exchange of information/ideas from teachers in the course.
E3	Is the teacher's expression of "performance expectations" accurate?
E4	Teachers assisting students during and after class.
E5	Care and respect for students.
E6	The stimulation of students' interest.
E7	Teachers' help with learning.
E8	Overall evaluation of teachers and courses.

C. Data Analysis Procedures

The study used mean completer to analyze missing continuous variables and mode completer to analyze missing categorical variables, eventually resulting in 7946 students enrolled in "Hard-Pure" courses. In total, 1114 face-to-face learning students (N_{female} = 614) and 6832 SPOCs learning students (N_{female} = 3599) were sampled for this study.

First, a set of ANOVAs and Chi-square tests were conducted to identify how the effect of teaching modes (SPOCs or Face-to-Face) correlated to academic performances (students' final grades) and to course evaluations. Second, Spearman correlation analyses were conducted to investigate the associations among all the study variables. Third, OLS (Ordinary least squares) regression models were analyzed by StataSE 15. Last, the heterogeneous analysis was conducted to verify the impact of teaching skills effect on college students' academic performance by instructional mode and age.

IV. Results

Teaching modes (Face-to-Face and SPOCs) and academic performance were explored using Spearman correlation analysis. First, from the overall sample, this study found a significant correlation between grade and teaching modes (r = -0.528, $p < 0.01$). This study also found that some dimensions of course evaluation (E1-E8) were also significantly correlated with academic performance: E1 teaching objectives and coursework (r = 0.023, $p < 0.05$), E2 the exchange of information/ideas from teachers in the course (r = 0.025, $p < 0.05$), E3 teachers' expressions of "performance expectations" (r = 0.024, $p < 0.05$), E4 teachers assisting students during and after class (r = 0.029, $p < 0.01$), and E6 the stimulation of students' interest (r = 0.026, $p < 0.05$). Second, in the face-to-face teaching environment, no variable in the course evaluation was significantly correlated with academic performance. Third, in SPOCs, E1 teaching objectives and coursework (r = 0.026, $p < 0.05$), E2 the exchange of information/ideas from teachers in the course (r = 0.027, $p < 0.05$), E3 teachers' expressions of "performance expectations" (r = 0.026, $p < 0.05$), E4 teachers assisting students during and after class (r = 0.033, $p < 0.01$), E6 the stimulation of students' interest (r = 0.029, $p < 0.05$), E7 teachers' helps with learning (r = 0.024, $p < 0.05$), these six variables are significantly positively correlated with academic performance. To further confirm the potential factors affecting academic performance, this study conducted regression analysis on the above factors.

Regression analysis results: this study used an OLS analysis with academic performance as the dependent variable. Table II shows the effectiveness of teaching modes and course evaluations in terms of academic performance. Specification a) shows OLS results without participant characteristics as controls, and specification b) shows OLS results with participant characteristics as controls. By controlling for the variables of the participants, the results show that when participant variables such as age, gender, and Ethnicity are controlled for, the results show that the SPOCs teaching mode leads to worse academic performance of the overall sample (although the correlation is not significant), which means SPOCs teaching is not conducive to improving performance in general. E4 teachers assisting students during and after class (β = 0.0739, $p < 0.05$) and E6 the stimulation of students' interest (β = 0.0723, $p < 0.01$) significantly and positively predicted academic performance. In general, the teaching mode can negatively predict academic performance, while E4 and E6 have a positive impact on academic performance.

TABLE II: Predicting the Academic Performance of Total Group

	Specification (1)		Specification (2)	
Teaching Modes	-0.0122	(0.0091)	-0.0260*	(0.0115)
E1	-0.0073	(0.0213)	-0.0100	(0.0213)
E2	0.0624	(0.0216)	0.0638	(0.0216)
E3	0.0206	(0.0213)	0.0231	(0.0213)
E4	0.0751**	(0.0155)	0.0739**	(0.0155)
E5	-0.0497	(0.0182)	-0.0474	(0.0182)
E6	0.0716*	(0.0175)	0.0723*	(0.0175)
E7	-0.0695	(0.0240)	-0.0700	(0.0240)
E8	-0.0749	(0.0247)	-0.0774	(0.0247)
Control Variables				
Ethnicity	NO		YES	
Age	NO		YES	
Gender	NO		YES	
Grade	NO		YES	
R^2	0.0022		0.0029	
Sample	7946		7946	

Note: *p < 0.05, **p < .01, ***p < 0.001. E1: teaching objectives and coursework. E2: the exchange of information/ideas from teachers in the course. E3: is the teacher's expression of "performance expectations" accurate? E4: teachers assisting students during and after class. E5: care and respect for students. E6: the stimulation of students' interest. E7: teachers' help with learning. E8: overall evaluation of teachers and courses.

Heterogeneity analysis: given that the internal factors of the learning environment on students' academic performance may be affected by teaching mode and age [29], this study conducted a heterogeneity analysis. The results are shown in Table III and Table IV. Table III shows that E4 (teachers assisting students during and after class) can more effectively improve the academic performance of SPOCs students (β = 0.0805, $p < 0.01$). Table IV shows that E4 and E5 (care and respect for students) can more effectively improve the academic performance of older students (β = 0.0642, $p < 0.05$; β = 0.1025, $p < 0.01$). It is worth pointing out that the results show that SPOCs online teaching may have an adverse effect on the learning outcomes of all students, but the effect is not significant.

TABLE III: Effects of Factors on Students' Academic Performance by Teaching Mode

	Face-to-Face	SPOC
E1	-0.0488	-0.0050
	(0.0527)	(0.0233)
E2	0.1087	0.0572
	(0.0526)	(0.0236)
E3	0.1487	0.0053
	(0.0531)	(0.0232)
E4	0.0231	0.0805**

	(0.0363)	(0.0172)
E5	-0.0988	-0.0402
	(0.0417)	(0.0202)
E6	0.1177	0.0650
	(0.0428)	(0.0191)
E7	-0.1249	-0.0616
	(0.0576)	(0.0263)
E8	-0.1210	-0.0694
	(0.0632)	(0.0268)
Control Variables		
Ethnicity	YES	YES
Age	YES	YES
Gender	YES	YES
Grade	YES	YES
R^2	0.0095	0.0026
Sample	1114	6832

Note: *p < 0.05, **p < 0.01, ***p < 0.001. E1: teaching objectives and coursework. E2: the exchange of information/ideas from teachers in the course. E3: is the teacher's expression of "performance expectations" accurate? E4: teachers assisting students during and after class. E5: care and respect for students. E6: the stimulation of students' interest. E7: teachers' help with learning. E8: overall evaluation of teachers and courses.

TABLE IV: EFFECTS OF AGE ON STUDENTS' ACADEMIC PERFORMANCE

	≤ 23	>23
Teaching Modes	-0.0294	-0.0035
	(0.0126)	(0.0485)
E1	0.0086	-0.0184
	(0.0416)	(0.0249)
E2	0.1747*	0.0220
	(0.0417)	(0.0252)
E3	-0.0006	0.0274
	(0.0430)	(0.0245)
E4	0.0928	0.0642*
	(0.0291)	(0.0184)
E5	-0.0745	-0.0345
	(0.0341)	(0.0216)
E6	0.0018	0.1025**
	(0.0333)	(0.0206)
E7	-0.0644	-0.0731
	(0.0458)	(0.0282)
E8	-0.1104	-0.0621
	(0.0435)	(0.0300)
Control Variables		
Ethnicity	YES	YES
Age	YES	YES
Gender	YES	YES
Grade	YES	YES
R^2	0.0074	0.0037
Sample	2108	5838

Note: *p < 0.05, **p < 0.01, ***p < 0.001. E1: teaching objectives and coursework. E2: the exchange of information/ideas from teachers in the course. E3: is the teacher's expression of "performance expectations" accurate? E4: teachers assisting students during and after class. E5: care and respect for students. E6: the stimulation of students' interest. E7: teachers' help with learning. E8: overall evaluation of teachers and courses.

V. DISCUSSION

A. Differences in Learning Outcomes between SPOCs and Face-to-Face Courses

The results of this study show that the SPOC teaching mode may have a negative impact on the academic performance of the overall sample. Therefore, compared with the face-to-face teaching method, SPOCs teaching is generally unfavorable for improving performance. This result is contrary to the research conclusion of Jia and Zhang [18], in which the SPOCs conducted by Jia and Zhang in the "Analog Circuit" course could be classified as "Hard-Applied" courses, in contrast to the course studied in this study, which could be classified as "Hard-Pure" courses. Jia and Zhang's course adopted a problem-based learning (PBL) method in the course. The course contained a lot of practical operation content (12 experiments and 25 projects), and included teaching activities such as operation videos, tests, online discussions, teamwork, and so forth. Some studies have also demonstrated the importance of the PBL teaching method used in "Hard-Applied" SPOC courses. For example, Zhang [30] adopted PBL in radiology SPOCs, and He [31] recommended that PBL should be widely used in medical education SPOCs. Their research results show that SPOCs can improve students' learning effect and interest, and they speculated that their results could apply to other "Hard-Applied" courses. The characteristics and teaching methods of "Hard-Pure" courses are obviously different from those of "Hard-Applied" courses. The courses are mainly based on theoretical derivation and lecturing. Therefore, there are relatively few opportunities for students to participate, interact, practice, and discuss in SPOCs, which leads to distraction and lack of effective knowledge acquisition. Thus, the "Hard-Pure" SPOCs need more detailed course design. For example, it is necessary to consider increasing the interaction between teachers and students, and it could consider combining various teaching methods and providing feedback to students through online platforms to improve student learning.

Based on the results of data analysis, first, this study believes that when exploring the difference in academic performance between SPOCs and face-to-face courses, it is necessary to consider the difference in course categories. Second, according to the differences in course characteristics, more targeted course design and teaching plan should be used in the SPOCs. Third, while "Hard-Pure" courses emphasize theoretical teaching, teachers might also consider bringing in collaborative, problem-solving, and task-based teaching methods to enhance classroom interaction and improve students' engagement and interest in SPOC courses.

B. Enhancing Students' Motivations and Learning Interests in SPOC Courses

Based on the results of the above data analysis, this study found that students in the lower grades are more inclined to choose SPOCs. It can be speculated that with the comprehensive and rapid development of distance education, more and more students have experienced distance education from various platforms, such as Khan Academy, Coursera, and so forth, in primary and secondary schools. Younger

students and prospective freshmen are increasingly accepting and tending to enroll in SPOCs.

This study found that stimulating students' interests in SPOC courses is one of the most effective ways to improve students' academic performance in "Hard-Pure" courses. This data result confirms the views of many scholars. For example, studies pointed out improving learning interests can effectively improve the online classroom students' satisfaction [32]-[34]. In the complex dynamic systems conceptual model of computer-mediated learning established by Marek and Wu [29], stimulating learning interest is an important factor in the model, and many empirical studies have also confirmed its importance [35]-[37]. For example, Dornyei pointed out that learning interest and learning motivation are significant factors that determine the learning effect [38]. Therefore, this study suggests that when designing and developing "Hard-Pure" SPOCs, teachers and online course designers should not only focus on the teaching content, but also need to use multimedia technology, teaching design, and other methods to stimulate students' interest in learning.

C. Strengthening Teachers' Assistance to Students in and out of Class

Another finding of this study is that teachers' help to students inside and outside the classroom can also effectively improve the academic performance of students in "Hard-Pure" SPOCs. This conclusion provides direct improvement suggestions for our design and development of "Hard-Pure" SPOCs. During the teaching process, teachers need to check during a lecture that students are actually acquiring the knowledge by asking them comprehension questions. If students are struggling to understand, the teacher might switch from verbally lecturing to drawing a picture on the board [39]. Outside of class, teachers can provide assistance to students in a synchronous or asynchronous way. There are already many technical tools to assist teachers in helping students after class [40], such as learning management systems, automatic answering machines, etc. A teaching assistant team or peer support activities can also be considered in SPOCs to reduce the pressure and burden on teachers.

To effectively improve the teaching quality of SPOCs, teachers play an important role. Although the teachers who offer SPOCs in this university have obtained the online teaching qualification certificate after one year of training, the SPOCs still have a negative impact on students' performance in the "Hard-Pure" courses. This suggests that it might also be necessary to continue to carry out relevant teacher training to strengthen teachers' abilities in stimulating students' interests and providing assistances both inside and outside the classroom, to improve the teaching effect of "Hard-Pure" courses.

With the increasing role of SPOCs in distance education, future studies may examine SPOCs in other course categories using similar research designs. Future research may employ qualitative research design to further examine students' perceptions toward SPOCs [41]. Distance education has been used as a synonym for Emergency Remote Teaching (ERT), which is fundamentally different in scope, application, and assessment, therefore, future studies may investigate how individual factors, teachers' factors, and technology factors influence students' performances in the context of ERT [42].

VI. Conclusion

This study investigates the learning effect of 7946 students in a "Hard-Pure" course in a large public university and further explores the aspects of the internal learning environment that affect its effectiveness. The current study contributes to theory building and inform instructional practices. This study found a significant correlation between grades and teaching mode (face-to-face or SPOC). SPOC courses have a negative impact on students' grades in the "Hard-Pure" courses. This study also found that some dimensions of course evaluation were also significantly correlated with academic performance. Teachers assisting students during and after class and the stimulation of students' interest significantly and positively predicted academic performance in SPOCs. Thus, the study provides implications in designing "Hard-Pure" SPOC courses: (1) the "Hard-Pure" SPOC courses need more detailed course design, (2) enhancing students' motivations and learning interests in SPOC courses, and (3) strengthening teachers' assistance to students in and out of class is key to improving the course's effectiveness.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Jining Han conducted the research and collected data; Jining Han and Jiayi Shi analyzed the data and wrote the paper; all authors had approved the version.

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