Using Design Based Research to Redesign Remote Proctoring for Online Learning Environments

Jining Han, Rentong Pan, Yuxin Gao, and Beibei Ren

***Abstract*—Online testing has been widely used in Chinese universities due to the development of distance education and the outbreak of COVID-19. The current research uses a design-based research (DBR) method aiming to design, implement, and assess remote proctoring of Chinese undergraduates and to further promote its effectiveness at Chinese universities. Across three iterations, a combination of qualitative data collection and analysis procedures were used to investigate the design of the remote proctoring. The results show that remote proctoring designers should add some new features to the remote proctoring and take into account test-takers' mentality. Finally, the study provides implications in designing remote proctoring.**

***Index Terms*—Remote proctoring, design-based research, online testing, misbehaviors.**

I. Introduction

Recently, due to the development of distance education and the outbreak of COVID-19, online testing has been extensively used in Chinese universities [1]. In particular, there has been a dramatically increasing need for online testing of Chinese undergraduates. The need for online testing has given rise to the need for remote proctoring. However, when the aim of online testing is to ensure the equity of a final classroom assessment, there are very few full-fledged remote proctoring systems available in China. Therefore, it is essential to focus on research in regard to remote proctoring systems.

Live remote proctoring systems generally refer to the process of webcam monitoring of students when they are taking exams: a proctor watches the live video feed of students taking the test and works to detect misbehaviors (i.e., cheating). If misbehavior is detected, the student's information will be recorded for future reference, or warnings will be sent to the student directly [2], [3]. Under such unusual circumstances as a pandemic, as well as in distance training and education, it is challenging, if not impossible, to proctor exams in traditional in-classroom settings. Instead, many universities have opted to have test-takers at scattered locations take online exams, for example, TOEFL iBT home edition.

In light of this, the remote proctoring setting of this research is a Chinese university where students themselves choose when and where they want to remotely take the test, which is supervised by proctors remotely. This study adopts a proctoring system predominantly utilized in the international realm and uses a design-based research method to study how various implementations of the system affect the behavior of Chinese undergraduates. Ultimately, the study investigates how to design and implement remote proctoring systems in order to promote the effectiveness of remote testing at Chinese universities.

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II. Background

A. Necessity of Remote Proctoring

As online learning has greatly developed, the relatively high-stakes final assessment toward the end of a semester has presented challenges to educators; the most difficult problem may be how to effectively implement online test proctoring. There has been a body of research highlighting the importance of online testing proctoring [4]-[8]. For example, Reisenwitz (2020) examined the differences between non-proctored and proctored online exam scores and found that significant differences existed between the two types. More specifically, there was a higher level of engagement with misconduct in non-proctored online exams. The author also pointed out that implementation of proctored online exams has a great likelihood of reducing or eliminating academic dishonesty [8]. Promoting online testing is an indispensable factor contributing to the development of teaching and learning [2]. With the widespread application of online testing, proctoring is necessary to prevent academic misconduct [9]-[12], to a significant extent. Effective test proctoring can greatly ensure the equity and fairness of online testing. In the future, testing will take various forms, of which online testing will be an important component. Therefore, it is of theoretical and practical value to examine, analyze, and improve the design of remote proctoring systems.

B. Application of Remote Proctoring Systems

Remote proctoring has witnessed development at both the conceptual and technical levels, and proctoring methods have been improved as well. Currently the primary international remote proctoring providers include Proctor U, OnVUE, PearsonVUE, Examity, and so forth. Hussin et al. (2020) thoroughly evaluated eight remote proctoring systems [13]. They concluded that a full-fledged proctoring system includes the following features: live human proctors, secure/encrypted transferring of data, the provision of training for both students and proctors, the ability for

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students to interact with proctors, live exam instructions, the ability for proctors to see students' screens, recording capability, automated proctoring, keystroke checking, web camera capability, audio recording, etc.

C. Gaps in Remote Proctoring Research

Among the studies related to remote proctoring research at Chinese universities, three problems regarding the construction of testing settings have not yet received adequate attention. First, most of the research looks into remote proctoring at a conceptual and theoretical level [14], [15], with less attention focusing on actual practices. That is to say, there has been little empirical research aiming to evaluate the adaptability and validity of remote proctoring. Second, a majority of previous research focuses on the improvement of hardware technology and automatic proctoring functions [16] that attempt to detect cheating using high-tech methods. The difficulty is that under remote circumstances, it is highly difficult to precisely pin down cheating behaviors. Advanced as technology may be, it does not guarantee successful implementation of a remote proctoring system. Third, the previous research mainly aims to refine remote proctoring systems by making hardware or software adjustments: the previous research rarely takes into account Chinese test-takers' subjective ideas about and attitudes toward the system. For example, the effect of students' degree of familiarity with the testing system on testing results [17], and the effect on testing equity caused by students' different affective attitudes have largely been ignored in the current research [3], [18]. Therefore, the study addressed the research question: How to redesign and implement remote proctoring systems in order to promote the effectiveness of remote testing at Chinese universities?

III. Research Design

A. Method

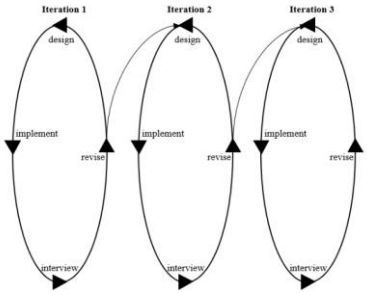

Fig. 1. Illustration of iterations in the current study.

This study adopts a design-based research (DBR) method. DBR is invariably rooted in an authentic education research context and situates research in immediate pedagogical contexts. The nature of DBR thus makes research "based on collaboration among researchers and practitioners in real-world settings and leading to contextually-sensitive design principles and theories" [19]. The purpose of DBR is not to test a hypothesis, but to refine education design step by step. As such, it is a research method that highlights iterative experiment intervention, implementation, and evaluation. It emphasizes the process of iterative research. For this reason, DBR was adopted in this research to design, implement, and assess the effect of remote proctoring systems at Chinese universities. The current study included three iterations, as illustrated in Fig. 1.

B. Context of the Study

This study sought to address a local issue at a southwestern large public university in China. The education program had been moved entirely online due to the pandemic. Undergraduates from this university could only take tests online. Hardware and equipment available at this university were used to create remote proctoring systems. This study recruited 10 student participants as test-takers, who did not have experience of online testing. The participants were told to think about and beyond the system during the testing, and in the meantime, they were encouraged to consider the flaws the system might have. The content of the test was adapted from the reading sections of the College English Test (CET). In total there were 30 questions, each corresponding to one point, for 30 points in total. The research team consisted of four people: a researcher, a research assistant, and two online proctors. Participants took the test at a regular office/dorm/home setting, which included a computer with access to internet, a cellphone, a desk, a video conferencing software, a microphone, and a web-camera, with no panoptical surveillance. The test-takers took the test alone in the location. The remote proctor issued orders remotely and monitored the whole process. One interview was conducted after the participant finished the test. Altogether three tests and three interviews were conducted with each participant.

C. Data Sources and Analysis Procedures

This study adopted qualitative data collection methods. The data consisted of the proctors' observation reports and three sets of interviews with the 10 participants. Though the number of participants may be relatively small, the data, consisting of three rounds of tests and interviews, collected at different times were sufficient to reach theoretical saturation in this DBR study [20]. The semi-structured interviews were designed to elicit learners' views of and responses to the remote proctoring, whereas the proctors' observation reports documented how participants worked within the remote proctoring environment in real time.

Interpretive methodology [21] was used to analyze the data. The anonymous interview recordings were first transcribed. The research team then read the transcriptions and analyzed them from the quasi-grounded theoretical approach. First, the team coded the data and made assertions; second, the team members met in person to discuss and finalize the assertions. Different opinions were discussed in order to reach agreement. Third, through cross-case analysis, the team compared the data and identified prominent themes in the data. The themes from this interpretive process were then used to redesign the remote proctoring.

IV. Results

Students' and proctors' feedback was collected immediately after each testing. Based on the feedback, we designed and revised the design. Please see Table I for the

descriptions of each design, the rationales, feedback, and revisions made to the design. Based on feedback and findings after each iteration, the revisions were primarily focused on three aspects: pre-test examination, real-time monitoring, and test-takers' preparation.

TABLE I: DESCRIPTIONS FOR EACH DESIGN, THE RATIONALES, FEEDBACK, AND REVISIONS MADE TO THE DESIGN

Iteration	Design Elements	Design Description	Rationale	Feedback
First	Pre-test verification	-Live identity verification: proctors compare the official ID card to the student's image, captured through the web camera in real time.	-Ensuring test-takers are who they say they are.	-Hard to compare the official ID through web camera (proctor).
	Real-time monitoring	-One proctor, one test taker.	-Ensuring the quality of proctoring.	-Spend a lot of time on proctoring (proctor).
		-Real-time monitoring through front-facing camera.	-Monitoring test takers while they are taking the exam. -Detecting unusual movement, additional person in the room, using other devices, etc.	-Checking textbook out of web camera's monitoring. -Using web camera's blind area, a roommate helps under the desk. -Hard to consistently monitor unusual eye movement (proctor). -Feel nervous and distracted, at the beginning.
		-Requiring students share computer screen with proctors.	-Detecting unusual movement such as searching information online, using software on computer, etc.	-Possible to search for information on other devices.
		-Sound detection: requiring students turn on microphone during the exam.	-Ensuring nobody helps test takers.	
Second	Pre-test verification	-No change.		-Using low resolution web camera to cheat during the ID verification.
	Real-time monitoring	-One proctor, three test takers. (*Changes made are presented in this row, the rest being the same as the previous round*)	-Reducing the time teachers must spend proctoring.	-Proctoring tests to 3 students simultaneously are time-consuming.
		-Setting up a second webcam using a tripod above students' heads.	-Minimizing the blind spots, making sure test-takers do not look for relevant materials or use electronic devices.	-Cheating reduced. -Pausing test through cutting of the Inter net. -Hard to define cheating behaviors(proct or). -Hard to consistently monitor unusual eye movement(proctor). -Need to prepare contingency plans if the Internet got cut out(proctor). -Ask a friend to help from behind the computer. -Wearing wireless earphones. -Hard to set up a camera above students' head. -Students feel at a loss the first time they access the test, which may distract their attention.
Third	Pre-test preparation	-Explaining the testing procedures, requirements and instructions through videos and pictures, which were sent to students 72 hours before the test; Recommending students contact the proctors 20 minutes before the test.	-Reducing distraction caused by unfamiliarity with the procedure.	-Increasing students' familiarity with the testing procedures.
		-Asking students to prepare high-resolution cameras, and good Internet connection; Asking them to prepare Wi-Fi and mobile Internet.	-Reducing cheating behaviors that was difficult to detect because of cameras' low-resolution and faulty Internet connection.	
		-Preparing alternate exam questions.	-Preventing students from taking advantage of a severed Internet connection to find the answers elsewhere.	
	Pre-test verification	-Using high-resolution cameras to check ID and automated ID checking system.	-Making sure students attend the test themselves.	-Hard to anticipate how surrogate test-taking is possible.
		-Asking students not to cover their ears with hair.	-Making sure students do not use wireless earphones.	
		-Using a separate camera to capture the testing environment.	-Making sure no relevant materials are visible and no external human assistance in the testing location.	
	Real-time monitoring	-One proctor, five test takers.	-Reducing the time teachers are required to spend proctoring.	-Save teachers' time and energy, but automated proctoring assistance is needed (proctor).

	-Real-time monitoring through front-facing camera. -Capturing students' face and hands.	-Reducing test proctoring blind spots. -Making sure students not look for relevant materials.	
	-The second camera is being put behind the students 45 degree diagonally.	-Reducing test proctoring blind spots.	-This webcam prevented me from seeking for help. -Students' cheating behaviors decreased.
	-Videotaping the whole process and saving the materials.	-Providing an opportunity to analyze potentially problematic behavior after the exam and storing data as evidence. -Ensuring nobody else is in the testing area.	-Students were getting anxious; they were particularly worried about if the records would affect their grades. They were also concerned about if it was graded mistakenly.

Pre-test examination: pre-test examination was modified along three dimensions. The first was identity authentication. In the initial design, students' identity was confirmed by comparing their face with their official ID. However, some students pointed out that due to the camera's low resolution, it was difficult for the proctors to tell the differences between the picture in students' ID and their face. The proctors also mentioned that the camera's low resolution made it possible for some students to find surrogate test-takers to take the test for them. In the third design, the resolution of students' camera, as an issue, was brought to the fore, which was also combined with auto identity authentication. For example, Yu (all pseudonyms) talked about the flaws of identity authentication in the second interview:

"I know my camera was not very clear, so it will not find out if the picture on my ID is correspondent to my face. I took my roommate's ID, and as expected, it didn't detect that."

The second change dictated by the research regarding students' use of wireless earphones. Some test-takers said that they could cover the wireless earphones with their hair; therefore, in the third design, students were required to have their ears exposed. For example, Xue mentioned this in the second interview:

"I put my hair down, wearing earphones, and playing my pre-recording answers via my wireless earphones. The proctors couldn't find that I had my earphones on."

The third change required checking the testing environment. In the third round of design, students were required to walk around the testing site with a camera in their hands.

Real-time monitoring: the modifications regarding real-time monitoring were made along four lines. The first was the scope of camera. In the first design, only the computer's front camera was used. The students said they could look for information or use electronic devices outside the camera's scope. The second design, however, added one more camera on the top of students' heads. Test-takers admitted that even though it could monitor their hands, it was not able to detect what they could do behind the computer. The third design required the computer's front camera to capture a test-taker's face and hands while a second camera placed at a diagonal behind the student simultaneously captured the student's whole body and the computer. For example, Hai explained in the third interview:

"After done with the three tests, I think the scope that the camera covers really matters. In the first round, there was only one front camera, with lots of blind spots. But in the third round, the camera was put behind me diagonally, which made it nearly impossible for me to do other things."

The second part of real-time monitoring concerned network interruption. Some test-takers said they could cut off the internet and suspend the test in order to find relevant information. The proctors also stated that they needed some contingency plans for emergency situations. In the third design, requirements were made regarding students' network, and a set of backup tests were also prepared for the proctors. For example, Chen mentioned in the second interview:

"When test proctoring is getting strict, if there're questions that I don't know the answer to, I can pause the test, during which time, I can look up for answers."

The third concerned the number of test-takers. The one-on-one test proctoring placed an unsustainable burden on the teachers. Therefore, in the third design, one teacher proctored five students simultaneously. The teachers said it saved time, but on the other hand, they were not able to keep an eye on all the students and monitor their unusual behaviors, if any. Therefore, it is recommended that test proctoring be implemented in combination with AI features such as action detection and automated video analysis.

The fourth set of changes made to the real-time monitoring process required recorded the proctoring process. The test proctor pointed out in the second report:

"We think that it is very hard to constantly keep an eye on test-takers' unusual behaviors, so we hope we can make use of AI assistance functions to help with the decision making. Besides, it is better to record the process of testing. This way, proctors can check back if they have any concerns, and it can also help save relevant data."

The third test proctoring was entirely videotaped and saved.

Test-takers' preparation: in the first and second rounds of design, the research team sent the test directions to the test-takers. These test-takers did not have any online test-taking experience; therefore, they all remarked in the first two rounds of interviews that online test proctoring distracted their attention and made them stressed. However, those negative feelings were alleviated as the test progressed. For example, Hai noted in the first interview that "I was a bit at a loss at first, but it was okay after I got used to it." Li commented in the second interview, "even though I read the test directions in advance, I still felt a bit anxious right before the test. Before the test it was stressful, but not in the middle of the test." In the third design, the research team sent the students the test directions in the form of visual explanations, which encompassed the preparation for and the procedures of the test in order to ease students' stress and unfamiliarity with the test. Song said in the third interview:

"If I'm aware of the whole procedure, I won't be distracted.

I will get stressed by the test itself, not by the online test proctoring environment."

V. Discussion

A. Building Trust through a Comprehensive Remote Proctoring System

Through the three rounds of design and revisions, we found the test-takers' cheating behaviors were reduced gradually. From the three rounds of interviews, we also found that the students indicated it was getting increasingly difficult to cheat in the tests. In the third interview, the participants admitted that they "couldn't cheat under this online proctoring environment on their own." The reliability of online proctoring also gained more and more acceptance among the participants. This is in line with Gonz áez-Gonz áez et al.'s 2020 research. Trust is the most important factor affecting schools, institutions, and test-takers when using online proctoring. It is of key value to ensure and maintain academic honesty and integrity in an online learning environment [22]. A well-designed remote proctoring system can effectively reduce cheating behaviors and maintain test equality [23], [24].

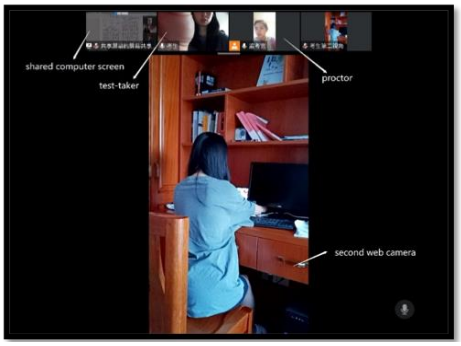

Fig. 2. Place a second camera diagonally behind students.

Previous research synthesized eight commonly-used online proctoring systems [13], [25], and identified various features that contributed to the improvement of the reliability of online proctoring, including live human proctors, students' interaction with proctors, monitoring students' screens, recording, automated proctoring, web camera, audio recording, etc. In addition to those features, this study puts forward the following functions that may promote the reliability of remote proctoring: the necessity for the computer's front camera to capture the test-takers' face and hands, the need to place a second camera diagonally behind students (as illustrated in Fig. 2), the need to make explicit requirements regarding students' network connection and the resolution of their camera, the need to capture the testing environment via camera before taking the test, the requirement that students have their ears uncovered, the use of automated proctoring to assist human proctoring, and the preparation of backup tests in case of network interruptions.

B. Taking into Account Test-Takers' Mentality

Some research has pointed out the need to take into consideration the effect that new remote proctoring environments have on students:

Some have pointed out that an unfamiliar environment may make students feel stressed and anxious [26], [27]. Hussein, Yusuf, Deb, Fong, and Naidu (2020) noted a majority of the students are accepting of the test proctoring method [13]; while they tend to get nervous after the test starts, the stress will soon diminish with the progression of the test. This study also found most test-takers were stressed and anxious before and during the initial phase of the test, due to the fact that they were not familiar with online test proctoring. As a result, in order to reduce students' stress, this study explained the proctoring requirements and procedures to the students via videos and pictures, and recommended test-takers contact the proctors 20 minutes before the test began.

C. Recommendations Regarding Remote Test Proctoring

After three rounds of design, revision, testing, and soliciting users' feedback, this study produced a design that was much improved compared to the first round. According to the interviews, the third design can provide remote test proctoring more efficiently. Based on these findings, we suggest that proctors will benefit from doing the following:

Before testing: providing clear guidance regarding the testing procedures, prescribing rules concerning students' network and camera, recommending students access the testing system in advance, preparing backup tests, preparing Wi-Fi and mobile network.

Authentication before testing: authenticating students' identity via automated authentication systems, human proctors checking test-takers' ID, asking students to take videos of the testing environment, and having their ears not covered by hair.

Live remote proctoring: using two cameras, one being the computer's front webcam, the other being put behind the students diagonally, asking students to turn on their microphone to check if it works, asking students to share their screen, proctors videotaping the testing process, and automated proctoring system assisting the human proctors.

After testing: saving the recordings and data.

VI. Conclusion

This DBR research adds to the reliability and comprehensiveness of a full-fledged design for remote test proctoring. The original design elements were enhanced to create a set of design principles for proctoring within an online education environment. The updated designs include: 1) Alleviating students' stress by means of pre-testing preparation, and in the meantime, prescribing rules regarding particular behaviors and equipment, and preparing for backup plans; 2) More closely conducting identity authentication and surveillance of testing environment before the test; 3) Increasing the camera scope to reduce cheating; 4) Making use of automated proctoring to assist human proctoring. The participants in this study were undergraduate students from mainland China. If the online proctoring system was to be applied in a different environment and among another group of test-takers, the mode might be subjected to change. Future studies can focus on online test proctoring designs in different environments, for tests of varying levels of stakes, for a large number of students taking online exams at the same time, and for different age groups,

in order to come up with effective online test proctoring systems for any situation.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Jining Han, Rentong Pan, and Yuxin Gao conducted the research and collected data; all authors analyzed the data and wrote the paper; Beibei Ren provided valuable revision suggestions for the paper; all authors had approved the version.

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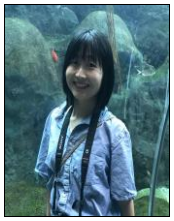

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