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Enhancing Chinese International Students' Motivation and Engagement in a STEM Subject in UK Higher Education: A Case of Gamification in Programming

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Programming courses, the entry of the digital world, can be overwhelming to freshers, especially for international students experiencing academic transition. To better understand and improve international students' programming learning experience, we conducted two studies. The first study identified international students' lack of intrinsic motivation and low engagement. The second study implemented a gamification approach to motivate and engage international students in programming learning and smooth their academic transition. The study showed positive results regarding the impacts of gamification on students' learning performance and intrinsic motivation.

CCS Concepts: • **Social and professional topics** → **Computing education**; **Information science education**.

Additional Key Words and Phrases: gamification, instructional design, motivation, engagement, learning performance

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1 INTRODUCTION

According to the UK Higher Education Statistics Agency, in the 2020/21 academic year, international students made up nearly a quarter of all students in UK higher education. A significant number of these students are enrolled in STEM courses. However, a series of challenges have been identified in programming learning, including high drop-out rates, low engagement in class, lack of learning motivation, negative academic emotions, unsatisfied learning outcomes, etc. [1, 2, 13, 16]. In addition, students with insufficient programming experience often find introductory programming courses difficult to learn, as it requires not only the understanding of a set of terms and functions, but also the ability to abstract problems, structure variables and produce algorithms to solve the problems [15].

As newcomers to the UK education system, international students face not only the challenges of dealing with above issues but also experience an academic transition period. Chinese students in particular have been encountering various transitional and acculturation problems because of the conflicts between the largely different socio-cultural educational systems in China and the UK.

In this study, we explore the application of gamification to improve international students' learning experiences in introductory programming courses at a British university. We focus our study on Chinese students since they form part

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of the largest group of international students. Gamification has been shown to be an effective tool to solve motivational problems and academic challenges [12]. In educational practice, gamification can be used by incorporating game design elements in learning activities within instructional systems to create an enjoyable learning atmosphere, motivate and engage students.

The aim of the study is to examine the effectiveness of gamification in improving international students' intrinsic motivation and learning performance in programming courses and smooth their academic transitional experience. The specific objectives are to:

(1) Identify the challenges and difficulties Chinese students met in an introductory programming course;
(2) Implement and evaluate the effectiveness of the gamification design on improving students' intrinsic motivation and engagement;
(3) Investigate the most effective game elements in the instructional design.

In this paper, we approach these objectives from two angles. First, provide an overview of related work in Section 2. In Section 3, we identify learning motivations and challenges by conducting a focus group discussion with Chinese students enrolled in a STEM course at a British university. Following up from this, we implemented gamification methods in the instructional design of a programming module, presented in Section 4. Conclusions and future work are discussed in Section 5.

2 LITERATURE REVIEW

2.1 Students' engagement in programming learning during academic transition

Academic transition refers to the phase when students adjust to a novel curriculum, with unfamiliar subjects, socio-cultural differences or other unexpected learning difficulties [6]. International students, especially whose previous educational and cultural backgrounds are drastically different from host students, are more likely to face challenges in the new learning environment. In a pedagogical context, these challenges may include the lack of academic, communication and language skills relevant to the new educational system; the mismatch of expectations regarding teaching and learning strategies between the perspectives of the international students and teachers, etc. For international students, these challenges may arouse academic anxiety, violated emotional states, a decrease of interest and value attitude towards their subjects, low engagement and interactions with instructors and peers, etc [9]. However, proper interventions and support from the institutions can help to soften the outcomes.

2.2 Intrinsic motivation in learning to program

In programming learning, students experience inefficient learning because of the lack of interest towards the course content, difficulty in understanding and visualizing the programming process, and most importantly, lack of intrinsic motivation [11]. The most mentioned motivational theory is Self-determination theory (SDT) [3]. It attempts to explain the motives of human behaviour, and asserts that people constantly seek challenges and novel experiences to develop and learn, driven by their innate needs of competencies, relatedness and autonomy. It divides motivations into extrinsic and intrinsic aspects, which influences people's behaviour [10]. According to SDT theory, the intrinsic drivers, i.e. the purely inherent willingness to do something, may result in more stable and sustainable engagement and persistence. On the contrary, with extrinsic motivation, people intend to do an activity or task mainly because of rewards or benefits upon completion, which is hard to maintain.

The SDT theory is instructional in the educational research and practices. It not only guides the pedagogy design step process in which appropriate game elements are implemented to motivate users by satisfying their needs, but also helps practitioners and researchers to understand users' psychological and behavioural changes [10]. The authors also suggested that future research should strengthen the instructional design to increase intrinsic motivation, in order to have longer term positive impact on learners' performances. With this study, we shed further light on the benefits of this suggestion.

2.3 Implementation of gamification in programming course

Gamification refers to applying game design components and mechanics in non-entertainment contexts to increase peoples' motivation and engagement, create an enjoyable experience and generate behavioural changes [5]. The past decade has witnessed the rapid proliferation and commercial success of gamification implementation in various fields, including healthcare, human resource management, education, etc. In educational field, Denmeade [4] describe gamified learning as a "design process" that reframes learning activities by applying game design principles to make the learning objectives and processes more appealing and achievable than traditional ways of teaching. The game attributes that can be applied in the educational fields range from a challenge, control, fantasy, immersion, communication, to goals [14].

By aligning existing theories of serious games and gamified learning in terms of the game attributes taxonomy in the educational context, Landers [14] has developed a psychological theory of gamified learning attempting to explain the mechanism of gamification in different learning contexts. The theory demonstrates the interaction among high-quality learning materials, gamification design, students' attitudes and behaviours, and their learning outcomes. The theory suggests that there are two types of processes that gamification affects learning, including a more direct "moderating" process, such as the quality of instructional content affect intuitively learning outcomes; and a more "mediating" process, such as the implementation of game elements led to learners' behavioural and attitude changes, and thus have impacts on their academic performances.

The Gamified learning theory provides a relatively comprehensive framework for evaluating the effectiveness of gamification. It draws attention not only to the psychological effects of game elements in specific contexts, but also learners' behavioural and affective changes during study. It also encourages researchers to examine the effectiveness of individual or combination of game elements in assisting learning activities under specific contexts, in order to better understand the mechanics of gamification in education.

3 STUDY 1: IDENTIFY LEARNING MOTIVATIONS AND CHALLENGES IN PROGRAMMING COURSE

3.1 Approach

In order to better understand the motivations of Chinese students enrolled in a STEM course at a British university, we conducted a focus group discussion. As pointed out by Facey-Shaw et al. [7], focus groups enable subjects to share their ideas and challenge each other's thoughts, which offers researchers more reliable and insightful information in investigating participants' motivation in gamification research. It is also appropriate when the population of interest share similar background.

Invitation emails with consent forms were sent to Chinese students of the Data Science program of a British institution. These students had already completed various lectures and practical programming sessions in the first semester of their studies. Nine Chinese students were randomly selected from those who responded to the invitation email for

the focus group. The topics of questions include students' learning motivations and expectations to study in the UK and their learning experience during the academic transition in the first semester. The first theme of the focus group interview questions is students' learning motivations and expectations to study in the UK. The questions includes:

(1) Why did you decide to study in the UK?
(2) Why did you choose the MSc Data Science program?
(3) What were your expectations regarding the learning and teaching method prior to departure?
(4) What were your expectations about the learning outcomes prior to departure?

The second theme of the focus group interview questions is students' learning experiences during the academic transition, in which the following questions were asked:

(1) How do you feel about the classroom environment?
(2) How do you describe your overall learning experience?
(3) What academic challenges did you meet?
(4) What support have you had in adapting to studying here?
(5) What did you perceive are the main differences between the study in the UK and your previous studies?

3.2 Results

We used NVivo to transcribe the focus group interview and anonymised all participants. After three rounds of coding of the transcript, several themes emerged as discussed below.

3.2.1 Low engagement and unsatisfactory performance in programming course.

In previous years, students' learning progress shows huge differences in practical programming sessions. The reason for such challenges is partially because students enrolled in the module hail from diverse backgrounds, and most of them don't have adequate programming skills. This observation is also reflected upon in the focus group discussion. As one interviewee put it: *"I only have a little bit of programming skills, and am not familiar with the use of functions in this session. I will appreciate if there are some brief introductions of functions before practising" (P4).*

In the programming module that the participants had already attended in the first semester, the focus is set on providing insights in the use of programming languages to analyse data. The programming exercises are designed to give an introduction to data analysis with an increasing level of difficulty over the course of the semester. The diversity of background knowledge exacerbates the gap of learning paces among students, which was identified as a dominant reason for participants' negative experience of this approach.

3.2.2 Lack of learning motivation as the root cause of unsatisfactory performance.

Another reason as indicated by the interviewees was that very few of them chose the program because they were passionate about data science. The dominance of the group was incentivized by extrinsic motives, such as pressure from parents and peers, rejections by other programs thus having no choices, and their hopes for a high salary after graduation. Therefore, they have inadequate intrinsic motivation of participating in non-credit learning tasks. Besides, participants experienced a disconnect between the worksheet material and their perception of solving cases as a data scientist. Students reported they were confused about the learning structure and learning objectives, and unclear about how to apply the knowledge from the sessions in their future career. The lack of relatedness leads to their feelings of meaninglessness, boredom and confusion.

3.3 Discussion

The study identified a series of motivational issues and academic challenges in the practical sessions of the programming module faced by the international students. This includes unwillingness to attend classes, dramatically different learning progress in classes, low engagement with classmates and course materials, negative academic emotions and lack of sense of belongings. From the study we found that the main reasons were their inadequate learning skills and knowledge, mismatch of learning and teaching expectations in the novel educational environment, disconnected with peers and instructors and lack of intrinsic motivation. This aligns with the previous study [8] that indicate international students as both novice programming learners and international sojourners, showing less motivation and resilience in the courses, and lack of relatedness to the program due to the unsmooth academic transition experience.

In summary, improving international students' intrinsic motivation and strengthening their connection with the program appears to be in urgent need in the instructional design. The study encourages us to implement the gamification approach in the programming course to provide better learning experience for international students in the UK.

4 STUDY 2: IMPLEMENTING GAMIFICATION METHODS IN INSTRUCTIONAL DESIGN

Aiming to address the short-comings identified in our first study, we developed new instructional learning materials to (a) make the content easier to follow and (b) to better illustrate the link between the knowledge taught and its application in the workplace. For this, we decompose instructional materials into different levels with instructions and tasks. We also set narrative storytelling in the home page of each session with real-life cases, to make students feel more connected to the program. Besides, game elements such as animated trailer (see Figure 1.left), role play, teamwork, points, leaderboards (see Figure 1.right), rapid feedback and avatars are implemented to create playful experiences and to increase their learning motivations.

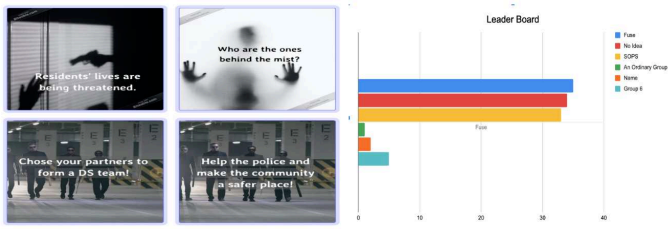

Fig. 1. Animated trailer of "crime investigation" (left) and real-time leaderboard (right) used in Week 7.

4.1 Methods

4.1.1 Programming course design.

We gamified materials of two practical sessions of a module focusing on big data analytics. The selected practical sessions provide introductory knowledge and hands-on experience of using Python programming in PySpark on Databricks to process big data. Databricks is a cloud-based collaborative platform where users can use programming languages, such as Python, SQL, R, to perform data analyses. PySpark is an open source application programming interface to support the collaboration of Python and the computational engine Apache Spark. A variety of learning activities regarding PySpark are also provided to develop their ability to identify questions and find solutions accordingly.

4.1.2 *Implementation of Gamification.*

The basis of the study was the gamified learning theory by Landers [14]. Adapted in the current study, a set of game elements (D) were applied based on the programming worksheet (A) to meet the learning objectives (B) and learning needs (C) identified in the first study (see Figure. 2). Animated trailers introducing the story-line of learning activities were created on biteble.com and sent to students prior to the start of the practical sessions [1]. The first session was set in the background of an airline's survival during the pandemic. In the second session, the task was to support local police in solving a criminal case.

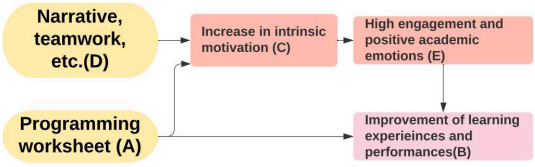

Fig. 2. The adaptation of Gamified Learning Theory in the current research.

4.1.3 *Participants Recruitment.*

Thirty-two Chinese students from the same STEM course mentioned in Section 3.1 were recruited via email invitation. Fifteen of the participants were female and seventeen were male. The dominance of the participants were at beginner level of programming.

4.2 Data Collection

To better evaluate the effectiveness of the gamification design, questionnaires, learning analytic and participatory observation were adopted to achieve triangulation. A questionnaire was distributed after the practical sessions to investigate students' learning experience of the gamification design. The questions used 5-point likert scales to measure their academic emotions, engagement, motivation, learning performances and their perceived effectiveness towards each game element. Students' behavioural data on the learning and teaching platform Blackboard, such as the time they spent on each task, the number of times they accessed the materials, were collected and analysed to measure their engagement and learning performances. The design of the questionnaire was inspired by the Intrinsic Motivation Inventory (IMI) [17], a commonly used instrument for research related to intrinsic motivation to assess participants' subjective experiences with strong validity support [18]. In this study, the questionnaire was modified for the specific context of introductory programming course, and was used to assess students' changes in the intrinsic motivations.

Observational data was collected during the session by note-taking, classroom observation, informal discussions, etc. The rubrics of the observational notes were based on the SDT theory, recording students' emotional and behavioural changes. The combination of the subjective data collected from students' self-report in the questionnaire, the objective data assessed from the learning analytics on Blackboard and the observational notes from the researcher as an outsider increased the reliability and validity of the study.

[1]Links to videos: video 1 - airline analysis and video 2 - crime investigation.

Type	*Positive Feelings*				*Negative Feelings*			
Feeling	Satisfactory	Enjoyment	Focused	Relaxed	Boredom	Hopelessness	Anxious	Angry
Median	4.0	4.0	4.5	4.0	2.5	3.0	3.0	2.0

Table 1. Medians of participants' level of agreement to "How do you describe your feelings to the session?" on a Likert scale of 5 (Strongly Agree) to 1 (Strongly Disagree).

4.3 Results

The study showed positive results of the gamification design on improving students' engagement, intrinsic motivation, academic emotion and overall learning experience. The data from the questionnaire, participatory observation notes and the learning analytics were analysed and reported following the themes below.

4.3.1 Student engagement.

The engagement was measured by students' perceived focus time addressed in the questionnaire, researchers' observational notes, their attempts to answer questions and their time spent on each task as recorded by the learning analytics function of Blackboard. 75% of the participants in the questionnaire indicated that they were focused during the class, in which 67% of the participants strongly agree the statements. Additionally, the dominance of the participants reported overall positive academic emotions and learning experiences of the session in the questionnaire as shown in Table 1.

This finding was echoed by our observation notes and informal discussion with participants during the classes. It was found that participants were immersed in the narrative settings, kept focused on the tasks, and actively engaged with classmates and the teaching team. The most striking finding was that more than half of the participants stayed in the classroom after the end of the session for another half to one hour, to finish their tasks. Students reported that they were more willing to ask questions to the teaching team than in previous sessions, more clear about the learning structure and understood their tasks and roles in the activities. The learning analytics function of Blackboard also indicated students' high engagement with the learning materials. 100% of the participants completed the 1st level of tasks in Weeks 6 & 7 with an average score of 93.65/100. Over half of them attempted to answer the more difficult and challenging questions in level 2 and 3, with average scores of 77.42/100. Interestingly, 71% of the students who did not finish the tasks made more attempts by themselves after the classes.

These results suggest that students' engagement was significantly improved. Besides, the gamified session showed long-term effects on students' learning behaviours, as they were self-motivated to put in more effort after the classes.

4.3.2 Students' intrinsic motivation.

As a psychological component, intrinsic motivation was mainly assessed by students' academic emotion, perceived academic confidence, relatedness and autonomy in accordance with the SDT theory in the questionnaire and our observations. According to the subjects' answers on academic emotions, they found the gamified design to be "very interesting", "impressive", "clear and attractive", and "attractive", which motivated them to take part in the learning activities. Some participants commented that they "hope to have more sessions like this" and "look forward to the next gamified class". Participants also made some suggestions regarding the gamification design. One participant commented that *"it would be better to release more materials for preview before the practical session, so that students have more confidence in the teamwork"*, which indicated that the participants were more motivated to participate in the workshop

and expected to perform better with classmates. These results indicate that participants' intrinsic motivation were increased, as they are willing to learn the programming course because they enjoy learning, rather than pushed by other extrinsic reasons.

In addition to the more positive academic emotion, the data of the questionnaire shows the majority (84%) of the participants agreed with the statement that the gamified session improved their academic confidence, and 47% of which strongly agreed. Respondents also reported increased relatedness to the classmates and the program. An average score of 4.32 out of 5 was shown in the 5-likert scale question asking students' agreement to the statement that gamification design increased their sense of belonging to the class. This includes their feeling of "closer relationship with the teaching team", "more interactions with classmates", "more active and comfortable learning atmosphere in the class" as they further explained in the short answer. Besides the increased sense of belonging to the class, students' relatedness to the instructional content and the data science program were also improved. As one informant commented: *"the gamification setting was strongly related to the real world, made me better understand the responsibilities of being a data scientist"*.

The autonomy of programming learning was strengthened by the gamification design as well. From the researcher's participatory observation, it was found that students' were excited and enthusiastic when deciding their team name. They also chose different strategies to finish the tasks within the team: some decided to work together on each task, while some chose to split and allocate the tasks to each member. Additionally, the participants expressed in the informal discussion during the session that they found it "interesting to figure out different methods of solving the questions by making more than one attempt, rather than simply copy and paste the answers from the worksheet".

In general, those results suggest that students' intrinsic motivation were increased by the gamification design, which was reflected in the improvement of their positive academic emotion, academic confidence, relatedness and autonomy.

4.3.3 Effective gamification elements.

Students' preferences and perceived effectiveness of each game element was evaluated in the questionnaire. The pie chart below in Figure 3 illustrates students' responses to their perceived most effective game elements increasing their intrinsic motivation to the programming course. Among the various game elements, the teamwork and narrative elements gained most popularity in the participants. More detailed explanations regarding the narrative element were gained from the descriptive answer, in which one participant commented: *"The animated trailer was very cute and interesting, created an immersive atmosphere and stimulated my sense of mission and exploratory curiosity, which motivated me to learn related programming knowledge to solve questions addressed in the trailer"*. This view was echoed by another informant: *"The story-line of each session gave me a chance to know more about the role of data scientists and how to use data analytic to solve cases, which increased my sense of meaningfulness and interests with the course"*.

When it comes to the perceived effectiveness of teamwork, 73% of the participants indicated that it was one of the most important components triggering their intrinsic motivation. For example, one respondee said that *"the teamwork elements made me feel like I'm not alone. I really like the moment we help each other and work out the problems together"*. This was also echoed with our observations, which indicated that although the progress of each team varies due to their diverse learning and skill backgrounds, there was only few negative emotions associated with failure on tasks or low rankings. Participants were helping each other and working together to figure out the problems they encountered. They were also encouraging their team members to make more attempts on the tasks.

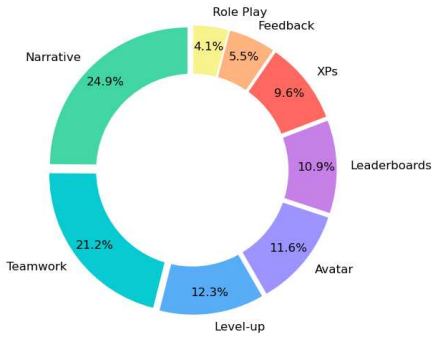

Fig. 3. Students' perceived effectiveness of each game elements in improving their intrinsic motivation.

Overall, narrative and teamwork were suggested as the most effective gamification elements on improving students' intrinsic motivation, by giving them a sense of mission, meaningfulness, belongings. The fulfilment of such needs aligns with the basic psychological needs as addressed in the SDT theory.

4.4 Discussion

Taken together, Study 2 aligned with the framework proposed by Landers [14] in the gamified learning theory and the intrinsic motivation explained by the SDT theory [3]: the game elements, especially the narrative and teamwork elements, enhance students' intrinsic motivation, and thus improve their engagement and foster as well as positive attitude towards programming learning. These psychological, behavioural and affective changes led to students' better learning experiences and performances.

Moreover, Study 2 expanded the framework by showing the feasibility and effectiveness of gamification practice in Chinese students' programming learning experience, a specific context and group of participants of which the gamification intervention has not been studied. This study also probed the mechanism of specific game elements in instructional design, and contributed to our understanding of those elements by answering the most effective game elements on improving students' intrinsic motivation in this context: narrative and teamwork elements.

Despite those successes, there are some limitations of the study. It could be argued that students might be motivated by the novelty of the learning and teaching form and their high performance was temporary. Besides, with a small sample size, caution must be applied, as the findings might not be representative and could be affected by the participants' personalities, learning backgrounds, learning styles, etc.

5 CONCLUSION AND FUTURE WORK

In this paper, we have explored how to increase Chinese students' intrinsic motivation in programming learning during their academic transition. The aims of the study was to identify the motivational and engagement challenges they faced in previous practical sessions, and to investigate the effectiveness of gamification in improving their learning experience.

The challenges associated with intrinsic motivation are identified by the first study, which encouraged us to apply the gamification approach to support Chinese students' programming learning experience during their academic transition. The second study incorporated a series of game elements in order to increase students' autonomy, relatedness, academic

confidence and positive academic emotion based on the SDT theory. Positive results in improving students' intrinsic motivation and engagement were observed in the second study. Teamwork and narrative elements were found as the most important components triggering students' sense of meaningful learning, belonging and autonomy in solving the problems with programming skills, which are strongly associated with their intrinsic motivation as illustrated in the SDT theory.

Notwithstanding the relatively small sample size, this work offers valuable insights into using innovative instructional design to support international students' learning in STEM subjects during their academic transition. The findings will provide guidance for future research that looks at other nationalities and mixed cohorts of international students. Additionally, aligning with the gamified learning theory [14] and the SDT theory [3], the study contributes to the theoretical and practical improvement of using gamification to improve students' intrinsic motivation in educational contexts.

We also propose several potential directions for further research based on our two studies. A further study could assess the long-term effects of the gamification in improving students' intrinsic motivation. In addition, considerably more work will need to be done to determine the impacts of each game elements on individuals in specific contexts.

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