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Asian Students' Cultural Orientation and Computer Self-Efficacy Significantly Related to Online Inquiry-Based Learning Outcomes on the Go-Lab Platform

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Abstract
Learning and teaching Mendelian genetics are central topics in school science. This study explored factors associated with the learning outcomes of Taiwanese junior high school students in an online inquiry learning environment. Research within face-to-face classroom settings had revealed that Asian students are more likely to be tutor-oriented and collectivistic learners. However, results of how these orientations affect learning in online environments are needed. In this analysis, seventh-grade students from Taiwan ($N = 290$) completed a genetics lesson using an Inquiry Learning Space (ILS) on the Go-Lab platform. Students were randomly assigned conditions in which support was provided either by general text or by an expert person in the form of a cartoon figure. In addition, students completed questionnaires assessing their cultural orientations, as well as their computer self-efficacy. Results revealed that the presence of a virtual expert did not influence students' learning outcomes. However, the extent to which students identified as collectivistic and their level of computer self-efficacy were positively associated with the learning outcomes. Students' computer self-efficacy was positively related to their behavioral intentions as well. These results illustrate the importance of Asian students' disciplined personality and computer self-efficacy for online inquiry-based learning.

Keywords Computer self-efficacy · Individualism-collectivism · Online inquiry-based learning · Authority · Behavioral intention · Genetics

Introduction

Students face a complex and changeable world with technological development and rapid social change. Therefore, many countries nowadays view cultivating students' self-directed learning ability as an important teaching goal. As a result, more and more educational systems in Asia have moved from content- and teacher-dominated science curricula toward an inquiry-based curriculum (Ramnarain, 2018), reflected in the natural science curricula particularly.

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According to the Natural Science Curriculum in the 12-year national education scheme in Taiwan, the Natural Science Curriculum should guide students in acquiring scientific inquiry ability, developing scientific attitudes, understanding scientific concepts, and applying scientific knowledge through the diversified ways of inquiry, reading, and practice (Ministry of Education, 2018).

However, Asian students are influenced by Confucian culture and tend to be tutor-oriented learners (Karnita, 2018; Liang & McQueen, 1999; Roberts & Tuleja, 2008). In the Asian educational environment, Asian students often passively listen to the knowledge imparted by teachers. Unlike the traditional Asian teacher-centered and knowledge-based teaching approach, in a learner-centered inquiry-based learning environment, learners construct knowledge through active exploration and view teachers as facilitators (Derting & Ebert-May, 2010). The active and self-directed nature of such learning might be challenging for Asian students.

Another trend is the introduction of online learning environments in the science classroom (Keller, 2005; Ray & Srivastava, 2020). Online learning environments facilitate easy access to experiential and self-directed learning: students can perform experiments via computer without being in a lab, reducing any possible dangers of the hands-on operation (de Jong et al., 2014). Furthermore, computer-assisted experimentation can speed up or slow down the processes teachers would like to present to their students. For instance, the genetic approach is too long to observe in a limited time, and teachers can speed up the process via an online learning platform. It is not surprising that computer-assisted instruction has become a current trend in science education and that Taiwanese researchers have also done much research to promote it (Chen et al. 2020).

Student learning progress in a computer-supported learning environment relates to their computer self-efficacy (Moos & Azevedo, 2009). According to the technology acceptance model, we can investigate users' behavioral intentions towards a technological system to see their acceptance of the system (Acarli & Sağlam, 2015). Furthermore, users' computer self-efficacy is relevant to their intention to use the online system (Chau, 2001; Hasan, 2007). Both elements play a key role in online learning for Asian students. Additionally, in a computer-supported inquiry-based learning environment, teachers can include scaffolds that assist students during their activities (Ping & Swe, 2004). Students' learning outcomes are influenced by the characteristics of the learning environment created by teachers (Phillips et al., 2010). Teachers must carefully consider whether and how to integrate support for their students when using such environments.

Macgilchrist et al. (2020) research shows that when discussing the future trend of education in a digital world, the collectivistic and individualism in culture must also be considered. Research on STEM-related inquiry learning environments often originates from America or Western Europe (Lee et al., 2019). Because authority plays an important role in Asian education, students tend to be tutor-oriented and rely on experts (Chen, 2002). Moreover, the students might be less used to computer-based learning. The specific characteristics of Asian students, like their more collectivist orientation, might be related to their learning processes and outcomes (Hwang & Francesco, 2010). This group of students might need other forms of support that better matches their preferred learning style to maximize their learning outcomes.

Considering the above, we explored how support in an inquiry learning environment affects Taiwanese learners' knowledge acquisition. Two versions of a learning environment on genetics were developed for the present study. We chose Genetics because it had been reported to help students learn effectively in computer-assisted inquiry learning (Sui et al., 2023; Thomson & Stewart, 2003). In the first version, guidance was presented through a virtual expert; in the second version, the same guidance was presented in plain text. The aim was to explore which type of visual presentation meets Asian students' needs. To better understand how the cultural factors and learner characteristics influenced students' learning in each of the designed conditions, we utilized the Go-Lab inquiry platform (Govaerts et al., 2013); we assessed student scores on an individualism-collectivism scale, their computer self-efficacy, and their behavioral intentions

Literature Review

Inquiry-Based Learning

Inquiry learning allows students to engage in scientific discovery processes and construct knowledge through the research means that scientists use (Keselman, 2003). Inquiry learning gained popularity among science educators because it creates a setting where students are invited to actively engage in meaningful science learning processes (Lim, 2004). Through inquiry learning, students not only obtain domain-related knowledge, but the use of inquiry-based instruction can also help them understand the scientific inquiry process and contribute to the development of the scientific reasoning process (Abdi, 2014; Hwang et al., 2015; Stender et al., 2018; Wilson et al., 2010). Nevertheless, there are challenges in implementing inquiry-based instruction in the science classroom. Inquiry learning is a complex process often represented as a cycle of interconnected phases. In their review, Pedaste et al. (2015) systematically reviewed different versions of the inquiry learning cycle presented in the literature, summarized them, and created an overview of the five main phases of the inquiry learning cycle. The

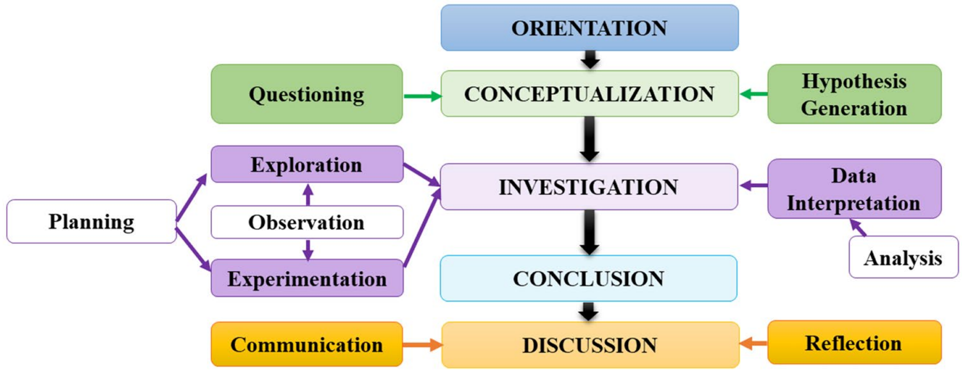

Fig. 1 Five general inquiry phases

five distinct phases of this analysis (also presented in Fig. 1) are orientation, conceptualization, investigation, conclusion, and discussion. Although the way students move through the cycle is not always linear, it is suggested to start with an orientation in which students familiarize themselves with the main variables in the learning environment. This was followed by a conceptualization phase where students explore the concepts related to investigations, which form the core of their activity and think about their research questions and hypotheses. During the investigation phase, experiments can be planned and conducted that allow students to answer questions or test hypotheses. Based on the collected data, conclusions will be drawn in the conclusion phase, and actual findings will be presented and discussed in the discussion phase.

Inquiry learning is often implemented in a computer-based learning environment that evolves around computer simulations. The simulations allow students to investigate topics that are hard to study through hands-on experiments because the associated experiments are difficult to perform in a classroom setting, dangerous, or hard to observe (Sahin, 2006). An additional advantage of computer-based inquiry learning is that guidance and support can easily be implemented in the learning scenario. This support is welcome since inquiry learning can be challenging for students (Apedoe, 2008). Since inquiry learning environments are highly self-regulated, students are expected to move through the inquiry learning cycle using their skills and prior knowledge. Asian students might struggle a bit more with the highly autonomous and self-regulated nature of inquiry learning that does not match the collectivist and authority-oriented Confucius culture Asian students are used to (van Aalst & Truong, 2010). Moreover, a study that (among other things) compared the Australian and Taiwanese students' inquiry learning activities revealed that high-performing Taiwanese students reported that they spent approximately 12% of their time on inquiry-related activities. For the Australian students, this time was more than 50% (Wang et al., 2021a, b).

Due to the values or beliefs of Confucian culture, Asian people tend to follow people with authority (Chen, 2002). Asians' tendency to follow authority is also reflected in their instructional preferences. A study by Liang and McQueen (1999) showed that unlike Western students, who tend to be peer-oriented learners, Asian students are more likely to be tutor-oriented learners, which means that their learning depends more on the teacher's instruction.

How to scaffold an inquiry-based learning environment to support the learning of Asian students is an interesting question. van Aalst and Truong (2010) combined constructivist elements with more instructive elements. A recent study comparing Australian and Taiwanese students suggests that more open forms of inquiry learning are associated with negative outcomes for Taiwanese students and that the teacher is considered an important facilitator of learning (Wang et al., 2021a, b).

Other researchers suggest visuals are important elements in user instructions for Asian students. Many scholars have drawn attention to the power of visuals in technical, scientific, and professional communication (Dagron & Tufte, 2006; Desnoyers, 2011; Ganier, 2000; Mijksenaar & Westendorp, 1999). A study by Li et al. (2021) showed that Chinese users are more likely to appreciate diverting, cartoon-like pictures, especially cartoons with detailed human depictions and cartoons with personification. However, Western users are likelier to appreciate strictly instrumental pictures, such as technical line drawings and detailed blow-ups.

Wilson (1983) distinguished authority based on the command from authority based on expertise. Command-based authority refers to giving orders backed by the possibility of punishment. Expertise-based authority is the advice provided by experts. Walton and Koszowy (2017) regarded arguments based on expert opinion as a type of cognitive authority. To explore the role of cognitive authority in supporting Asian students' learning, in this study, we designed two learning environments with or without virtual experts. These two learning environments addressed the same course content but delivered the content to students differently. In one, the content was introduced simply in the text; in the other, it was presented by virtual experts. The aim is to understand whether presenting information via the cognitive authority of a virtual expert improves Asian students' learning outcomes.

Go-Lab Online Learning Platform

Many free learning websites and learning platforms have been introduced in recent years. For example, the PhET website provides interactive mathematical and scientific simulations. The game-like format attracts students to explore and learn science actively. In addition, WISE features inquiry activities in step-by-step inquiry phases (Gobert et al. 2002). In the WISE system, teachers can monitor students' responses to understand their progress (Raes & Schellens, 2015). They can also encourage students to brainstorm on designated scientific topics for collaborative problem-solving and knowledge integration (Chiu & Linn, 2011; Raes et al., 2016).

Compared with WISE, Go-Lab focuses on integrating existing virtual laboratories, remote laboratories, and application resources on the platform to help students cultivate scientific methodology skills during the inquiry process (Govaerts et al., 2013). Teachers can design online learning environments based on the phases of inquiry-based learning in the inquiry learning spaces (ILSs) with embedded online labs and apps and share them with students (Dikke & Faltin, 2015; de Jong et al., 2014; Gillet et al. 2013). For example, teachers can embed the interactive science simulation the PhET website provides into ILSs. This simulation can motivate students to learn in a game-like environment (Moore et al., 2014). In addition, the Go-Lab teaching platform allows teachers to provide students with apps they need in the inquiry process, such as the hypothesis tool, the table tool, the observation tool, the conclusion tool, and the reporting tool. Furthermore, this platform has many ready-made online learning environments in ILSs designed and shared by many educators and classified according to topics and languages. In our study, we integrated the virtual rabbit laboratory, hypothesis tool, table tool, observation tool, conclusion tool, and report tool to allow students to conduct inquiry activities in the genetics lesson.

Individualism and Collectivism

The culture in East-Asian countries differs from that in western countries, which also impacts the educational approach to STEM-related topics. Individualism-collectivism (IC) refers to the social connections between individuals (Bochner & Hesketh, 1994). In an individualistic culture, people are regarded as independent individuals with unique characteristics. In contrast, people in a collectivist culture consider themselves interdependent in the groups to which they belong (Markus & Kitayama, 1991). According to Wagner and Moch (1986), individualists put personal interests before the group's needs. In the present study, the Taiwanese students are rooted in Confucianism's family environment and kinship, resulting in a special form of authority-directed orientation. In the East, people's identity and self-awareness can only be established in indivisible groups (Dien, 1999). As a result, Asian parents tend to inculcate collectivism (following group norms and obeying authority) in their children rather than individualism (autonomy and self-reliance), the mainstream American culture (Chen, 2002). Collectivists consider the well-being of the group they belong to their priority, even if they sacrifice their own needs; this might be reflected in students' motivations and career perspectives in STEM education. For East Asian students, the desires and beliefs of their family and community shape their STEM-related beliefs and choices. Within the East-Asian approach to STEM education, achievement and self-discipline are important, and the system is highly content and exam driven (Wahono et al., 2020). Parents are highly invested in their children's education, specifically related to STEM, because it is considered important for students' future careers (Worsham et al. 2016). However, it is unclear whether Asian students' obedience to group and family norms and authority impacts their learning processes and outcomes. Therefore, this study explores whether the collectivistic tendency of students' personalities positively affects their learning outcomes. In addition, cultural factors related to collectivism and individualism might impact how students use technology for learning purposes.

Computer Self-Efficacy

Bandura (1986) defined self-efficacy as someone's judgment of his ability to organize and execute a series of actions. It does not directly measure people's skills but is related to their judgments about any skills they possess. For example, a driver's self-efficacy can involve their judgment of their ability to drive on a highway or a curved mountain road. Therefore, computer self-efficacy represents a person's perception of their ability to use computers to perform a certain task in an effective way (Compeau & Higgins, 1995; Murphy et al., 1989). The level of self-efficacy refers to the level of difficulty that people think they can conquer (Brief & Aldag, 1981). Those with lower self-efficacy are less likely to persist when facing difficulties, while those with higher self-efficacy tend to overcome challenges (Compeau & Higgins, 1995). Research on computer-self efficacy in online learning environments indicates that students' computer self-efficacy is linked to the experienced satisfaction with online learning environment and their intention to use it in the future. While most studies show a positive relationship between ICT use and learning, results for East-Asian countries are mixed. Levine and Donitsa-Schmidt (1997) suggest that individuals with low computer self-efficacy may refuse to use a computer or experience anxiety when using one.

Since Asian students do not use computer-assisted learning as general as students in Western countries, computer self-efficacy becomes crucial to their learning effectiveness (Wu et al., 2010). Research has shown a positive relationship between students' computer self-efficacy and their use of computer-based learning environments, their attitudes towards using the computer for learning, and their outcomes and performances in these learning environments (Baturay et al., 2017).

Behavioral Intention

The *Merriam-Webster Dictionary* defines "intention" as "a determination to act in a certain way" (Merriam-Webster, 2003). Based on this definition, behavioral intention can be the degree to which a person intends to perform or not perform certain behaviors in the future. Warshaw and Davis (1985) pointed out that if behavioral intention (BI) is viewed as a continuous variable over a 0–1 interval, a value close to 1 indicates a conscious decision to perform a particular behavior, and BI close to 0 indicates a conscious decision not to perform the behavior. A value close to 0.5 suggests that the person is not consciously deciding whether to enact or not to enact a particular behavior.

Davis (1989) incorporated behavioral intention as an element in the technology acceptance model (TAM), a diagnostic tool for evaluating and predicting whether digital device users accept a new IT system. TAM is based on the theory of reasoned action (TRA) and the cost–benefit paradigm. TRA, a social psychology theory, indicates that an individual's specific behavior depends on his behavioral intention, which is determined by his attitude and subjective norm (Davis et al., 1989). The cost–benefit paradigm demonstrates that people tend to evaluate the cost and benefits before making decisions (Davis, 1989; Davis et al., 1989). Research findings suggest that Asian students, in general, have a positive intention to use computers; this seems to be influenced by a variety of factors, including perceived usefulness (Al-Adwan & Smedley, 2012), ease of use, enjoyment of using the computer, (Zhao et al., 2011) and the social factors (Lin & Lu, 2011). The collectivist orientation of students and teachers in Asian schools might influence technology acceptance and behavioral intent to use computers. Huang et al. (2020), for example, found that for Chinese students, the perceived usefulness is not significantly related to the intention to use the internet for learning. These results are reflected in other studies that did find a relation between perceived usefulness and behavioral intention for Chinese students but noted that this relation was weak compared to the relationship found in a comparable US sample. On the other hand, the relation between the influence of the subjective norm (whether a person thinks that significant others find it important that he uses technology) was stronger for Chinese students (Srite 2006). The role of the collective versus the individual is reflected in these results.

Research Purpose

Based on the above research background and motivation, the primary research purpose was to examine what factors are related to Taiwanese junior high school students' learning outcomes in an online inquiry-based learning environment. Therefore, the research questions were as follows:

2.1. Does a virtual expert in the inquiry learning spaces (ILSs) affect Taiwanese junior high school students learning outcomes?
2.2. Are Taiwanese junior high school student learning outcomes related to individualism-collectivism or computer self-efficacy?
2.3. Do students' computer self-efficacy beliefs positively affect their behavioral intentions to use ILS?

Research Methods

Participants

The researchers recruited seventh-grade students from their teachers at a junior high school in Taiwan. The inquiry activity took place during their winter science camp to participate in the research. A total of 290 7th graders (around 12–13 years old) engaged in the inquiry activities, including 178 girls and 112 boys. Among them, 27 students did not complete the pre-test, 9 did not finish the post-test, and 4 did not participate in the pre-test and post-tests. Therefore, the researchers excluded their data from the analysis. These 7th graders had not yet learned genetics before the study, so it was an opportunity to see if working in ILSs could help them develop a deep understanding of genetics. Students were randomly assigned to one of the two conditions: in the intervention condition, a virtual expert provided guidance, and in the control condition, only textual guidance was provided.

Lesson Structure

The lesson was designed according to the inquiry learning cycle of Pedaste et al. (2015). The orientation phase introduced the topic by presenting a drawing of rabbits displaying

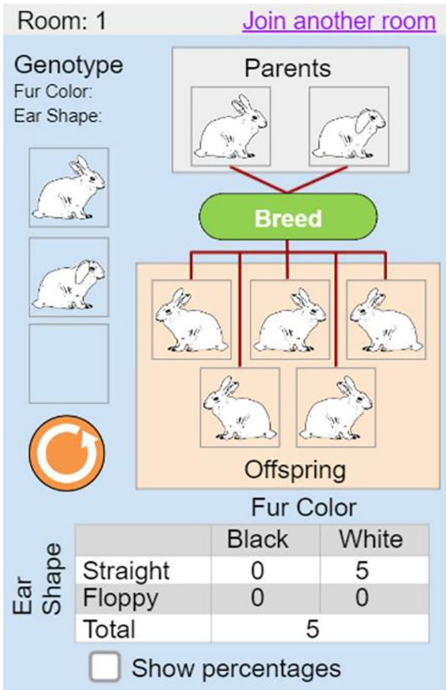

Fig. 2 Online virtual rabbit genetics laboratory

different characteristics. Subsequently, the introduction phase introduced the genetics-related terminology used in the unit and familiarized students with the inquiry learning cycle. In the conceptualization phase, students formulated their hypothesis based on given research questions so that they hypothesized the ratio of offspring with different genotypes or phenotypes. In the investigation phase, students conducted virtual rabbit experiments and recorded the experimental data (see Fig. 2 for a screenshot of the virtual rabbit genetics lab students used). In the conclusion phase, students drew conclusions based on the experimental results. The discussion phase helped students reflect on the inquiry process by introducing Mendel's law. Finally, students were required to complete a questionnaire about individualism-collectivism, computer self-efficacy, and behavioral intention to use ILSs. The ILSs were presented in Chinese, the students' native language. The content of inquiry activities followed one of the themes of the Biology Curriculum Framework, namely genetics.

Instruments

The instruments in the study included a domain knowledge test and a questionnaire focusing on individualism-collectivism. Considering possible language barriers for students, the researchers designed the domain knowledge test and the questionnaire originally in English and then developed Chinese versions. First, the English versions were developed based on the related literature; the Chinese versions were translated from English. Then, two professional translators were asked to translate the Chinese versions back into English and compare them with the original English versions. The focus was on the accuracy of the core concepts rather than matching the exact words in the translation. When there was a discrepancy between the original versions and the back-translation, the item wording was revised if necessary.

The domain knowledge items were selected from question banks provided by textbook suppliers and revised by three experienced biology teachers to match the goals of the lessons. After reviewing the related literature, the researchers drafted the questionnaire, addressing individualism-collectivism, computer self-efficacy, and behavioral intention to use ILSs. Three science education experts then revised the questionnaire's initial version to establish construct validity. After that, the researchers conducted a pre-test in Taiwan with sixty-one 7th graders.

Domain Knowledge Test

The domain knowledge test was designed by Sui et al. (2023), which has proven reliable and valid. The test includes a pre-test and post-test to measure students' understanding of traits, gametes, dominant genes, recessive genes, and monohybrid cross concepts. The pre-test and post-test each included eleven 5-option multiple-choice questions worth 10 points each, for a maximum score of 110 points. To avoid errors caused by random guessing, when the student did not know the answer, they could check the option "I do not know" and get zero points on this question. It's a parallel test, and the questions on the pre-test and post-test were similar but not identical, and the concepts tested were the same.

Individualism-Collectivism Scale

The individualism-collectivism scale was based on the one developed by Wagner (1995): which comprised 5 factors: personal independence and self-reliance (5 items), the importance of competitive success (5 items), the value placed on working alone (3 items), subordination of personal needs to the group (4 items), and the effects of personal pursuits on group productivity (5 items). However, after conducting an exploratory factor analysis, two items from factor 1 and one item from factor 5 were deleted, resulting in a revised scale with a total of 17 items. All of the items use a 5-point Likert response scale (strongly agree to strongly disagree). 5 points for strongly agree, and 1 point for strongly disagree. Items 1–8, 10, and 16–17 were reversed coded, with high values indicating high collectivism. In addition, the researchers used Cronbach's α to assess the reliability of the revised scale, which showed good internal consistency for each factor: factor 1 (0.770), factor 2 (0.885), factor 3 (0.764), factor 4 (0.809), factor 5 (0.815), and for the overall scale (0.629).

Computer Self-Efficacy

The items on the computer self-efficacy scale were selected and modified from work by Compeau and Higgins (1995), Ong et al. (2004), and Pituch and Lee (2006) to examine students' subjective perception of their computer skills, including 8 items in total. The original scale had 9 items; however, the researchers deleted 1 item based on the exploratory factor analysis. Thus, the revised questionnaire used in this study contained 8 items. All of the items used a 5-point Likert response scale (strongly agree to strongly disagree). 5 points for strongly agree, and 1 point for strongly disagree. A higher score meant higher computer self-efficacy. The scale's reliability was 0.925, which indicates good internal consistency.

Behavioral Intention to Use ILS

The definition of behavioral intention referred to the work by Acarli and Sağlam (2015) and Davis et al. (1989), modified to fit the context of the digital learning platform in this study. The behavioral intention to use ILS scale was designed to examine students' subjective willingness to use ILSs and the willingness to continue using them or to recommend others to use them in the future, including 4 items (in total). All of the items adopted a 5-point Likert response scale (strongly agree to strongly disagree). Five points for strongly agree, and 1 point for strongly disagree. A higher score meant a stronger behavioral intention to use ILSs. The scale's reliability (Cronbach's alpha) was .951, which indicates good internal consistency.

Exploratory Factor Analysis

The researchers checked the results from the pre-test with reliability analysis and exploratory factor analysis (EFA). Reliability analysis was used to test the internal consistency of the various dimensions in the scales making up the questionnaire, including the Individualism-collectivism scale, the computer self-efficacy scale, and the behavioral intention to use the ILS scale. Factor analysis was used to delete items with insufficient explanatory power. Cronbach's alpha was used for reliability analysis. After analysis, each scale's reliability was higher than .7, which showed that the questionnaire's various scales and dimensions had good internal consistency (George & Mallery, 2019). Exploratory factor analysis was used to explore the scales' factor structure. The KMO and Bartlett sphere test values for the questionnaire were .70, $p < .001$, which showed that these variables were suitable for factor analysis. Truong and McColl (2011) believe factor loadings should be greater than 0.5 for better results. Therefore, the researchers removed items with factor loadings less than 0.5. If an item loads more than .5 on two or more factors, the item covers several constructs (cross-loading); the item can also be considered for deletion (Farrell & Rudd, 2009). After deleting items based on factor loading and cross-loading, the factor loadings for the remaining items were greater than .5. The revised questionnaire (shown in Appendix) was then used in this study.

Data Analysis

According to the research purpose and instruments, researchers used SPSS 23.0 statistical software to analyze the quantitative data. Cronbach's α coefficient was adopted to test the internal consistency of the various dimensions of each scale. The higher the α value is, the more reliable

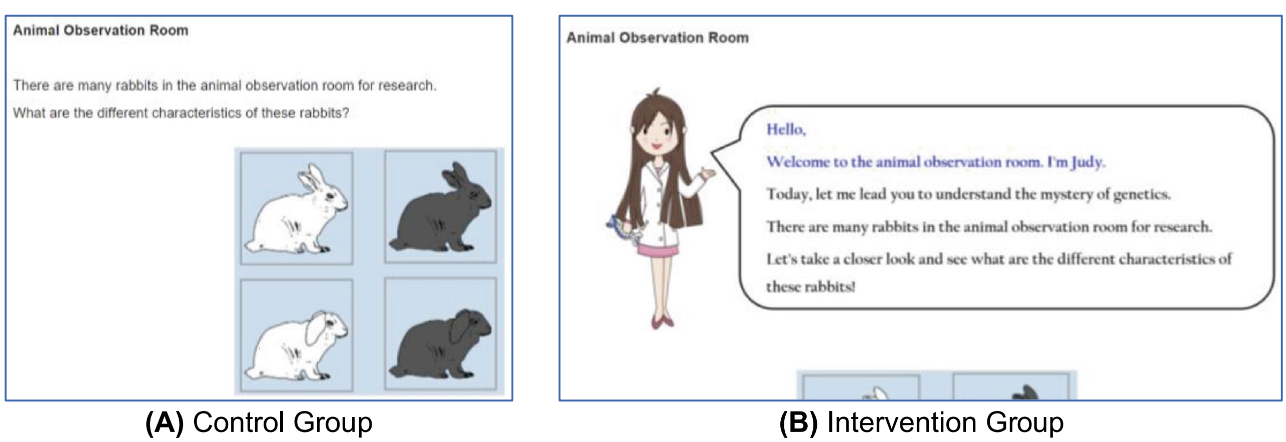

Fig. 3 Presentation of instructions in the learning environment for the control (text only) and intervention (expert guidance) versions (The text in this figure has been translated from Chinese.)

Table 1 Paired samples *t*-test comparison of pre-test and post-test domain knowledge scores

N	Pre-test		Post-test		*t*	*p*	Cohen's *d*
	Mean	*SD*	Mean	*SD*			
250	44.76	24.20	73.76	21.44	−16.70	< 0.001	1.268

The maximum possible score was 110 points

the survey is, and the α value greater than 0.7 is considered reliable. Descriptive statistics were used to analyze students' scores in the domain knowledge test, including average and standard deviation. Independent samples *t*-test was used to compare the differences in students' learning outcomes between low and high collectivism, as well as low and high computer self-efficacy. It was also adopted to compare the differences in students' learning outcomes between control and intervention groups. A paired *t*-test was used to see if students significantly improved learning outcomes in their domain knowledge scores after experiencing ILS.

Research Procedure

Researchers recruited seventh-grade students from their teachers at a junior high school in Taiwan to participate in the study. The aim was to explore the factors that affect students' learning outcomes. It was during COVID-19 that students were unable to attend classes at school. Therefore, all participants engaged in the lesson at home. Participants were required to complete the pre-test to evaluate their prior knowledge; they were given 30 min to complete the test online. Then, all students individually worked through a genetics lesson in an ILS from the Go-Lab platform; this session lasted around 2 h. Students were divided into two groups—the control group and the intervention group; students in the intervention group engaged in the lesson following the guidance of a virtual expert. The virtual expert was designed as a female with a friendly image and caring for students. The virtual expert introduced the lesson in a dialog box to provide guidance (Fig. 3A). However, the control group students engaged in the lesson without a virtual expert; they had only textual instructions (Fig. 3B). The way the virtual expert conveys the sentence seems to speak to the students. For example, "Let's take a look and see the different characteristics of these rabbits." Nevertheless, the control group is more like instructions without emotion. The virtual expert was presented throughout the genetics lesson, and students could not ask questions of her. After engaging in the lesson, students were requested to fill out the questionnaire in Go-Lab. It aims to assess their level of individualism and collectivism, computer self-efficacy, and behavioral intentions to use ILSs. Finally, students were asked to complete the post-test to evaluate their learning performance; they were given 30 min to complete the test.

Results

Students' Learning Outcomes

To investigate whether students' performance improved after engaging in the ILS genetics lesson, the researchers conducted a paired samples *t*-test. A total of 250 participants had both pre-test and post-test scores. The analysis showed that participants' mean scores improved significantly from pre-test to post-test ($t = -16.70$, $p < .001$, effect size = 1.268). Because the seventh graders had not learned genetics yet, their scores on the pre-test were relatively low. However, their mean score improved after working through the lesson from 44.76 to 73.76, as shown in Table 1.

An independent *t*-test comparison of students' pre-test and post-test performance by condition was conducted to check any differences in students' domain knowledge between the control and intervention groups. Table 2 shows no significant difference in the performance of the two groups of students in the pre-test ($t = -0.753$, $p = 0.452$, effect size = 0.097) or the post-test ($t = 0.401$ $p = 0.689$, effect size = 0.052), indicating no significant difference in learning outcomes between the two groups.

Comparison of Learning Outcomes Between Low- and High-Collectivism Students

The researchers divided students into high, middle, and low groups based on their individualism-collectivism scale scores to investigate whether students' collectivism levels were related to their learning outcomes. Items 1–8, 10, and 16–17 of the individualism-collectivism scale were reversed coded, with high values indicating high

Table 2 Independent samples *t*-test comparisons of pre-test and post-test domain knowledge scores for control and intervention conditions

	Pre-test		Post-test	
	Control	Intervention	Control	Intervention
N	130	111	130	111
Mean	43.85	46.22	74.69	73.60
SD	24.38	24.35	19.50	22.64
t	−0.753		0.401	
p	0.452		0.689	
Cohen's *d*	0.097		0.052	

Table 3 Descriptive statistics for pre-test and post-test domain knowledge scores for low- and high-collectivism students

	Low					High				
		Pre-test		Post-test			Pre-test		Post-test	
Factor	*N*	Mean	*SD*	Mean	*SD*	*N*	Mean	*SD*	Mean	*SD*
1	82	45.85	24.39	72.80	19.89	79	45.06	25.21	77.09	20.58
2	67	50.30	23.55	73.13	21.34	82	42.56	25.52	73.78	21.00
3	71	46.62	23.90	74.93	21.57	102	45.88	24.39	75.00	20.71
4	62	40.97	20.46	70.65	21.18	107	43.46	25.11	77.20	19.46
5	127	42.05	22.51	71.89	21.81	107	47.66	26.12	77.85	19.48
All	60	48.33	23.73	73.17	21.90	64	46.41	26.87	79.22	20.18

Factor 1 is the "personal independence and self-reliance"; Factor 2 is "the importance accorded to competitive success"; Factor 3 is "the value attached to working alone"; Factor 4 is "the subordination of personal needs to group"; Factor 5 is "the effects of personal pursuits on group productivity"

collectivism. Therefore, students with higher scores on the individualism-collectivism scale tend to be more collectivistic, while those with lower scores tend to be more individualistic. Students whose scale scores for a particular factor (or the overall scale) were equal to or higher than those of 73% of the participants were categorized as the high group. Those with scale scores equal to or lower than 27% of the participants were categorized as the low group. Our study emphasized the comparison between the low collectivism group and the high collectivism group. An independent sample *t*-test showed no significant differences in the pre-test scores between the high and low group students on any factor or the overall scale. Students in these groups, therefore, had similar prior knowledge of genetics before engaging in the lesson. However, students who showed high collectivism for factors 4 (the subordination of personal needs to a group) and 5 (the effects of personal pursuits on group productivity) had higher post-test domain knowledge scores than those characterized as low collectivism for these factors (Factor 4: $t = -2.04$, $p = 0.043$, effect size = 0.322; Factor 5: $t = -2.19$, $p = 0.030$, effect size = 0.228). Table 3 shows descriptive statistics for pre-test and post-test scores by high- or low-collectivism group per factor and overall, while the results of the *t*-tests are shown in Table 4.

Comparison of Learning Outcomes Between Students with Low and High Computer Self-Efficacy

Students were divided into high, middle, and low groups based on their computer self-efficacy scale scores to investigate whether students' computer self-efficacy was related to their learning outcomes. Students whose scores were equal to or higher than those of 73% of the participants were categorized as the high group, and those whose scores were equal to or lower than those of 27% of the participants were categorized as the low group. According to the frequency distribution table results, students with scores of 4.0 or more were assigned to the high group, while those with scores of 3.0 or less were assigned to the low group. Our study emphasized the comparison between the low computer self-efficacy group and the high computer self-efficacy group.

Independent samples *t*-tests were conducted to compare the performance of the low and high groups in the domain

Table 4 Comparison of pre-test and post-test domain knowledge scores for low- and high-collectivism students

	Number		Scale scores		Pre-test (low vs high)			Post-test (low vs high)		
Factor	Low	High	Low	High	*t*	*p*	Cohen's *d*	*t*	*p*	Cohen's *d*
1	82	79	2.00	3.00	0.20	0.840	0.032	−1.34	0.181	0.212
2	67	82	2.80	3.60	1.91	0.059	0.315	−0.19	0.853	0.031
3	71	102	3.00	4.00	0.20	0.844	0.031	−0.02	0.983	0.003
4	62	107	3.25	4.00	−0.70	0.485	0.109	−2.04	0.043	0.322
5	127	107	3.00	3.50	−1.74	0.083	0.230	−2.19	0.030	0.288
All	60	64	3.03	3.48	0.42	0.674	0.075	−1.60	0.112	0.287

Factor 1 is the "personal independence and self-reliance"; Factor 2 is "the importance accorded to competitive success"; Factor 3 is "the value attached to working alone"; Factor 4 is "the subordination of personal needs to group"; Factor 5 is "the effects of personal pursuits on group productivity."

Scale scores equal to or higher than 73% of the participants were categorized as the high group, while those equal to or lower than 27% were categorized as the low group

Table 5 Comparison of pre-test and post-test domain knowledge scores for students with low and high computer self-efficacy

	Pre-test		Post-test	
	Low	High	Low	High
N	80	65	80	65
Mean	42.38	46.00	70.75	79.08
SD	23.77	24.61	22.32	20.67
t	−90		−2.31	
p	0.370		0.022	
Cohen's *d*	0.149		0.387	

Table 7 Comparison of pre-test and post-test domain knowledge scores for students in group H5 + C and group L5 + C

	Pre-test		Post-test	
	L5 + C	H5 + C	L5 + C	H5 + C
N	40	25	40	25
Mean	40.50	48.00	68.50	84.80
SD	23.85	28.72	23.38	19.39
t	−1.139		−2.914	
p	0.259		0.005	
Cohen's *d*	0.284		0.759	

knowledge pre-test and post-test. There was no significant difference between these groups on pre-test scores, $t = -0.90$, $p = 0.370$, effect size = 0.149. However, students with high computer self-efficacy performed significantly better than those with low computer self-efficacy at post-test, $t = -2.31$, $p = 0.022$, effect size = 0.387. Descriptive statistics for pre-test and post-test scores are shown in Table 5.

The Correlation of the Pairwise Combination of Computer Self-Efficacy, Collectivism Factor 4, and Collectivism Factor 5 with Students' Learning Outcomes

Because factors 4 and 5 of the individualism-collectivism scale and computer self-efficacy are potentially related to students' learning outcomes, the researchers used pairwise combinations to explore their joint relation with students' learning outcomes. First, the researchers combined collectivism factor 4 and computer self-efficacy. Students in the high group for computer self-efficacy and factor 4 of individualism-collectivism were termed group H4+C ($n = 33$). In contrast, students in the low group for computer self-efficacy and factor 4 of individualism-collectivism were termed group L4+C ($n = 23$). Pre-test and post-test scores on the domain knowledge tests for groups L4+C and H4+C were compared using independent *t*-tests. There was no significant difference in the pre-test scores between group L4+C and group H4+C ($t = -.523$, $p = .603$). However, students in group H4+C had significantly better post-test scores than students in group L4+C ($t = -3.033$, $p = .005$, effect size = .853) (see Table 6).

Similarly, the researchers combined collectivism factor 5 and computer self-efficacy to explore their joint relationship with students' learning outcomes. Students in the high group for computer self-efficacy and factor 5 of individualism-collectivism were termed group H5+C ($n = 25$). In contrast, students in the low group for computer self-efficacy and factor 5 of individualism-collectivism were termed group L5+C ($n = 40$). Independent samples *t*-tests were conducted to compare the performance of group L5+C and group H5+C on the pre-test and the post-test. There was no significant difference in pre-test scores between group L5+C and group H5+C ($t = -1.139$, $p = 0.259$, effect size= 0.284). However, group H+C students performed better than group L5+C on the post-test ($t = -2.914$, $p = 0.005$, effect size = 0.759) (see Table 7).

Collectivism factors 4 and 5 were combined to explore their joint relation with students' learning outcomes. Students in the high group for both factors 4 and 5 of individualism-collectivism were termed group H4+5 ($n = 51$), while students in the low group for both factors were termed group L4+5 ($n = 41$). Independent samples *t*-tests were conducted to compare the performance of group

Table 6 Comparison of pre-test and post-test domain knowledge scores for students in group H4 + C and group L4 + C

	Pre-test		Post-test	
	L4 + C	H4 + C	L4 + C	H4 + C
N	23	33	23	33
Mean	40.00	43.64	69.13	84.24
SD	24.86	26.08	21.09	13.47
t	− .523		−3.033	
p	0.603		0.005	
Cohen's *d*	0.143		0.853	

Table 8 Comparison of pre-test and post-test domain knowledge scores for students in group H4 + 5 and group L4 + 5

	Pre-test		Post-test	
	L4 + 5	H4 + 5	L4 + 5	H4 + 5
N	41	51	41	51
Mean	43.17	48.63	69.51	82.35
SD	21.38	27.20	20.61	17.62
t	−1.078		−3.221	
p	0.284		0.002	
Cohen's *d*	0.223		0.670	

L4+5 and group H4+5 on the pre-test and post-test. There was no significant difference in the pre-test performance between the two groups (t = −1.078, p = 0.284, effect size= 0.223). However, students in group H4+5 got higher post-test scores than students in group L4+5 (t = −3.221, p = 0.002, effect size = 0.670) (see Table 8).

The Correlation Between Students' Computer Self-Efficacy and Their Behavioral Intentions to Use ILSs

Using Pearson's product-moment correlation test, the researchers further examined the correlation between students' behavioral intentions to use ILSs and their computer self-efficacy. The result shows a significant correlation between behavioral intention and computer self-efficacy (n = 275, r = 0.206, p = 0.001) (data not shown).

Discussion

A Virtual Expert Has No Significant Impact on Asian Students' Learning

The results of our show that students demonstrated a significant improvement in domain knowledge through participation in online inquiry-based activities. There was no significant difference in performance between students in the control and intervention groups. These results indicate that Asian students, who are typically tutor-oriented (Liang & McQueen, 1999) and prefer visually rich content (Li et al., 2021), are capable of learning effectively without the guidance of a virtual expert. In other words, the absence of a virtual expert did not hinder the learning outcomes of Asian students.

The results might be explained by the fact that within the present study, we used a static agent, allowing for little interaction between the virtual character and students. Therefore, future research can focus more on the interaction between virtual experts and students. For example, researchers could compare a group of students who have access to a virtual instructor or expert for answering questions with a group that has a non-adaptive static instructor or does not have access to such support. Alternatively, emergent robotics technology could be leveraged to develop a robot peer or expert and analyze the impact of students' natural language interactions with such technology on the learning process and outcomes.

Collectivistic Students Tend to Learn More

The results of our study showed that for the factors of "personal independence and self-reliance" (Factor 1), "the importance accorded to competitive success" (Factor 2), and "the value attached to working alone" (Factor 3), there were no significant differences in post-test scores between high and low collectivist students. However, for the factors concerning "the subordination of personal needs to a group" (Factor 4) and "the effects of personal pursuits on group productivity" (Factor 5), there were significant differences between students who tended to be more collectivistic and more individualistic. In other words, not all factors were related to students' learning outcomes. The research results of Wang et al. (2021ab) showed that cultural orientation indirectly influences students' online performance, which is slightly different from the findings of this study. The difference might be because Wang, Xiong, and Liu's study focused on examining the effect of students' tendency to be horizontal or vertical collectivists on online performance. In contrast, this study emphasizes the relation of other aspects of individualism-collectivism with student performance.

Research by Baumann and Krskova (2016) showed that emphasizing school discipline in Asia countries positively impacts students' academic performance. Similar results were also found in this study. Students who tend to be collectivistic on factors 4 and 5 of individualism-collectivism will put the group's needs as the top priority instead of their pursuit. When such students with disciplined personalities confront command-based authority, backed by the possibility of punishment, they are more willing to sacrifice their interests for the group's benefit (Smith et al. 1998) and obey the group's norms, resulting in better learning outcomes.

Students with High Computer Self-Efficacy Tend to Learn More

The results of this study showed that students with higher computer self-efficacy had higher post-test scores and indicated the importance of students' computer self-efficacy in online learning. Since the Go-Lab system is an online inquiry platform, students must use computers to study on the Go-Lab system. However, due to a lack of infrastructure and insufficient internet quality (Basu et al., 2007), Asian students are less prevalent than Western students in using computer-supported learning. Although there are computer-related courses in Taiwan, parents often restrict students from using computers at home. As online teaching will be an instructional trend in the future, we suggest that future research can try to understand why Taiwanese parents do not permit their children to access computers at home. Further research is needed where teachers work with parents to allow students greater access to computers at home, facilitating student computer self-efficacy and enhancing their online learning effectiveness. Students' computer self-efficacy is particularly critical for online learning in such a social context. Many studies showed that learners' computer self-efficacy was significantly and positively correlated with their learning (Chen, 2017; Simmering et al., 2009). Our study also found that students' computer self-efficacy was significantly related to their online inquiry learning outcomes.

The Synergistic Effect of Computer Self-Efficacy, Collectivism Factor 4, and Collectivism Factor 5

This study showed that when combining computer self-efficacy with factor 4 of individualism-collectivism for grouping, the difference between group L4+C and group H4+C (p = 0.005, effect size= 0.853) is more significant than grouping students based on computer self-efficacy (p = 0.022, effect size= 0.387) or factor 4 of individualism-collectivism (p = 0.043, effect size = 0.322). Similarly, when combining computer self-efficacy with factor 5 of individualism-collectivism for grouping, the difference between group L5+C and group H5+C (p = 0.005, effect size = 0.759) is more significant than grouping students based on computer self-efficacy (p = 0.022, effect size = 0.387) or factor 5 of individualism-collectivism (p = 0.030, effect size = 0.288). It reflects synergistic effects between computer self-efficacy and collectivism factor 4 or 5. Also, when combining factor 4 and 5 of individualism-collectivism for grouping, the difference between group L4+5 and group H4+5 (p = 0.002, effect size = 0.670) is more significant than grouping students based on factor 4 (p= 0.043, effect size = 0.322) or factor 5 (p = 0.030, effect size = 0.288) of individualism-collectivism. These two factors also produced a synergistic effect. The synergy between these factors means combining students' computer self-efficacy and the personalities of obeying group discipline have a stronger relationship with their learning outcomes. Such findings suggest that Asian schools' emphasis on computer learning and school discipline can potentially create a productive online learning environment for students.

Correlation of Computer Self-efficacy and Behavioral Intention

Previous study results obtained by Ariff et al. (2012) found a relationship between students' computer self-efficacy and their behavioral intentions toward using an online system. A similar result can also be seen in this study. Students with higher computer self-efficacy tended to consider learning through ILSs a wise choice. They were also more willing to recommend others to use ILSs in science learning.

Conclusions

This study explored factors related to Taiwanese seventh-grade students' online inquiry-based learning outcomes. The results showed that interacting with the ILS resulted in significant learning outcomes for Taiwanese students in both conditions. How the guidance was presented to the students (in plain text or through the virtual expert) did not affect learning. Such findings might be because there is little interaction between avatars and students in the learning environment. Future research researchers can design a robot and analyze the benefits of interaction between the robot and students on student learning. Students' computer self-efficacy was associated with learning outcomes and behavioral intentions to use ILS. This suggests that activities that foster students' computer self-efficacy might positively influence their learning outcomes in inquiry learning environments and increase their willingness to use online inquiry platforms for learning. Such findings suggest the importance of Asian students' computer self-efficacy for their online inquiry-based learning. Students who tended to be collectivistic on factor 4 and factor 5 of individualism-collectivism were likelier to show significant learning outcomes. These findings reflect that students who value the group's needs more than their pursuits and are willing to obey the teacher's norms tend to engage more in the online lesson and thus learn more effectively. Said results illustrate that the emphasis placed on school discipline in terms of collective or Confucius perspective in Asian countries has positively impacted students' academic performance. Participants in this study were limited to adolescents, and perhaps a disciplined disposition is critical for students learning at this age. However, such findings should not be extrapolated to students in other age groups. Our results also showed the synergistic effect between computer self-efficacy and collectivism in factor 4 or factor 5. Moreover, collectivism factors 4 and 5 together produced a synergistic effect. Last but not least, students' behavioral intentions to use ILSs were significantly related to their computer self-efficacy.

Appendix

A. Individualism-Collectivism

Factor 1: personal independence and self-reliance

1. *Only those who depend on themselves get ahead in life.
2. *To be superior, a person must stand alone.
3. *If you want something done right, you've got to do it yourself.

Factor 2: the importance accorded to competitive success

4. *Winning is everything.
5. *I feel that winning is important in both work and games.
6. *Success is the most important thing in life.
7. *It annoys me when other people perform better than I do.
8. *Doing your best isn't enough; it is important to win.

Factor 3: the value attached to working alone

9. I prefer to work with others in a group rather than working alone.
10. *Given a choice, I would rather do a job where I can work alone rather than doing a job where I have to work with others in a group.
11. Working with a group is better than working alone.

Factor 4: the subordination of personal needs to group

12. People should be aware that if they are part of a group, they will sometimes have to do things they do not want to do.
13. People who belong to a group should realize that they are not always going to get what they personally want.
14. People in a group should realize that they sometimes are going to have to make sacrifices for the sake of the group as a whole.
15. People in a group should be willing to make sacrifices for the sake of the group's well-being.

Factor 5: the effects of personal pursuits on group productivity

16. *A group is more productive when its members do what they want to do rather than what the group wants them to do.
17. *A group is most efficient when its members do what they think is best rather than doing what the group wants them to do.

Note: * Items 1–8, 10, and 16–17 were reversed coded, with high values indicating high collectivism.

B. Computer Self-Efficacy

1. For me, operating a computer is easy to learn.
2. For me, a computer is easy to use.
3. It is not difficult for me to operate a computer proficiently.
4. It is very easy for me to use a computer to do what I want to do.
5. I am confident that I can learn a wide variety of computer skills.
6. I do not have to rely too much on other people's instructions to learn how to use computers.
7. I can learn how to use a computer by observing how others use it.
8. I am able to use a computer as long as I have a reference book or a computer manual with me.

C. Behavioral Intention

1. I consider that learning science through ILS is a wise choice.
2. During my school years, I consider using ILS for science learning.
3. I am willing to recommend others to use ILS in science learning.
4. In general, my willingness to use ILS in science learning is quite high.

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Data Availability All data and materials are available from the authors.

Code Availability IBM® SPSS® Statistics Base Edition.

Declarations

Ethics Approval This study followed ethical standards for social science research.

Consent to Participate Informed consent was obtained from all individual participants included in this study. All of the participants volunteered to participate in the study.

Competing Interests The authors declare no competing interests.

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