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Effects of Personal Construal Levels and Team Role Ambiguity on the Group Investigation of Junior High School Students' Programming Ability

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Abstract: Concerns regarding the high demand for skilled personnel in the science, technology, engineering, and mathematics (STEM) fields underline the importance of developing advanced information technology (IT) and programming skills among job candidates. In the past 10 years, computer programming has regained considerable attention because of rapid developments in computer programming technology. Advocates claim that computer programming cultivates other skills, including problem solving, logical thinking, and creativity. Education systems worldwide are developing courses to instruct students in programming and computational thinking. Although the importance of computer programming has been widely recognized, the systematic evaluation of the effectiveness of teaching methods and conditions that promote the learning of programming knowledge and skills has received little scholarly attention. This study thus investigated the moderating roles of learners' construal levels and their team role ambiguity in the context of group investigation in junior high school programing courses. In this study, junior high school students were divided into pairs to develop Arduino projects. Students applied programming abilities to complete a task involving the use of Arduino boards to simulate the operation of traffic lights. Major research findings indicate that construal levels play a significant role in moderating the relationship between programming ability and learning outcome; however, role ambiguity does not significantly affect this relationship. Theoretical implications are discussed, and managerial implications are suggested.

Keywords: programming ability; learning outcome; cooperative learning; group investigation; construal level theory; Arduino

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1. Introduction

Concerns regarding the high demand for workers in the science, technology, engineering, and mathematics (STEM) fields have emphasized the relationships between STEM skills and career trajectories [1]. An estimated two-thirds of all new jobs in STEM-related areas are associated with information technology (IT) [2]. Recent research estimated that the demand for advanced IT and programming skills will rapidly increase by as much as 90% between 2016 and 2030 [3]. Therefore, economies must strengthen their workforces with more talented programmers [4]. Since today's middle school students will begin their careers in the 2030s, and people with programming abilities will undoubtedly be an in-demand minority [3], it is essential to cultivate and enhance their programming abilities now.

In the past 10 years, computer programming has regained considerable attention due to the rapid development of computer programming technologies. Advocates for the discipline claim that it is also beneficial to other skills, including problem solving, logical thinking, and creativity [5]. Education systems globally are developing courses to instruct students in programming and related skills [6]. Specifically, these courses shape students' basic programming concepts and computational thinking, with the purpose of providing students critical skills that can be applied to the information society. Hence, effective education in programming can also influence the personal problem-solving skills that students require in daily life [7]. Therefore, the education policies of several countries necessitate updates to the computer science curriculum attempts to train future computer scientists by integrating programming courses into the elementary and general education curriculums [7]. Although the importance of computer programming is widely recognized, the systematic evaluation of the effectiveness of teaching methods and conditions that promote learning programming knowledge and skills has received little critical attention [5].

In Chuang and Lee's [8] study of the impact of contractual level on programming abilities, they demonstrated a significant moderating effect of construal level on the relationship between programming abilities and learning satisfaction in the context of cooperative learning. This study aimed to investigate the relationships between personal characteristics (construal level), personal skills (programming abilities), and group dynamics (team role ambiguity) on the programming learning performance in the context of junior high school students' learning performance on their science and technology courses. Under group investigation, students were divided into pairs to develop their Arduino projects. Students applied programming skills to complete a task involving the use of an Arduino board to simulate the operation of traffic lights. As a result, this study investigated the factors influencing students' learning performance in science and technology courses and proposed practical strategies and tactics for instructors.

2. Literature Review

2.1. Cooperative Learning

Cooperative learning is a teaching method that divides students into groups to encourage interaction to enhance their learning performance and interpersonal behaviors [9–11]. From this definition, cooperative learning is further inferred to involve the following characteristics:

(1) It is a systematic teaching strategy;
(2) At least two student groups are included in the overall study group;
(3) Each student group has a common learning goal;
(4) Students discuss collaboratively within their groups to achieve the goal;
(5) The strategy promotes students' cognitive, social, and emotional development, as well as further group learning.

Research on cooperative learning has verified the strategy's considerable benefits in enhancing student learning effectiveness. For instance, Munir et al. [12] emphasized that cooperative learning can improve students' deep learning and critical thinking abilities. Johnson and Johnson [13] reported that cooperative learning encourages face-to-face interaction between students to solve problems, exchange opinions, and help each other. Nattiv [14] noted that cooperative learning enables students to collaborate in groups to achieve common goals. Finally, Ishler et al. [15] contended that, compared with competitive and personal efforts, cooperative efforts can improve performance and productivity, establish positive and supportive relationships, and improve mental health in participating students.

Group investigation (GI) is a primary method of implementing cooperative learning. Shachar and Fischer [16] reported that the implementation of GI involves the following general steps and guidelines:

(1) The class determines subtopics after a teacher presents the main topic and organizes students into small research groups.
(2) Groups plan how to proceed with their work.
(3) Groups perform their investigations.
(4) Groups plan how to present their findings to the class.
(5) Groups present their findings.
(6) The teacher and students evaluate the presentations.

The influence of GI on students' learning has also been extensively investigated. For example, Shachar and Sharan [17] asserted that GI based on positive peer interaction in small groups increases students' motivation to learn and provides flexibility and variety in the content and pace of teaching and learning. Rosiani, Parmin, and Taufiq [18] noted that an effect on the critical thinking and the scientific communication skills of students ensues after the implementation of GI in the learning process. Parinduri et al. [19] argued that students' conceptual knowledge and skills exhibit enhanced performance with the application of GI (compared with conventional learning). Shidiq et al. [20] revealed that employing the GI method in terms of group topic selection, planning, plan execution or action, analysis and evaluation, group presentations, and assessments in a social science learning context yielded changes in students' interpersonal skills of communication and cooperation.

In summary, to improve student learning outcome (LO), we used GI as a teaching strategy with the following steps:

(1) Divide students into pairs and inform them of the project's main subject (using Arduino boards to simulate traffic light functions).
(2) The central theme is divided into two subthemes (circuit wiring and programming), and each team plans a work strategy.
(3) Each group conducts investigations on the subthemes, and teachers provide assistance according to the needs of the research groups.
(4) After completing the subtheme investigations, each group integrates their investigations with the major themes and informs the overall group of their findings.
(5) The teacher inspects the students' work and concludes the project work session.

2.2. Programming Abilities

Fidai et al. [21] indicated that interventions that involve use of Arduino (a programming language that can control the operation of machinery) and Scratch (a programming language with a graphical user interface) had an overall positive effect on students' STEM academic performance and their perceptions of the STEM fields. Scratch and Arduino play a discernibly crucial role in current programming curriculums. Topalli and Cagiltay [22] evaluated students who participated in a fourth-grade introductory programming course, determining that using Scratch can improve their performance in graduate courses. This finding suggests that Scratch facilitates the longer-term enhancement of programming abilities (PA) among engineering students.

In this study, students first undertook eight Scratch courses, completing a test after each course. The instructor regarded each test result as representative of the student's PA at the time. Therefore, we hypothesized that:

Hypothesis 1 (H1). *Students' PA in the Arduino course is positively related to their levels of LO.*

2.3. Construal Level Theory

According to the research of Liberman et al. [23], psychologically distant events are defined as events that are not present in an individual's direct experience of reality. The authors claimed that an individual's direct experience of current reality is the starting point for anchoring psychological distance. Any other differences are related to psychological construal.

Trope and Liberman [24] noted that construal level theory (CLT) conceptualizes image proximity as to whether an image is concrete or artificial and near or far. Several studies have reported that CLT can be used to explain how small psychological distance and large psychological distance affect the interpretation, judgment, and behavior of consumers [23–26]. CLT asserts that when consumers form the psychological representation of their decision-making choices, time, space, or sensory psychological distance increase the level of abstraction. Kim et al. [27] contended that high-level explanations are usually regarded as relatively abstract, context-independent, and superior representations of main features [27]. In contrast, low-level explanations are often viewed as relatively specific, context-dependent, and subordinate representations of secondary features, such as the feasibility of results.

Vered and Nira [28] observed that CL affects how people make decisions. For example, people will seek relevant information as guidance when making decisions. Decision-makers with higher CL usually gather more information to ensure that they can visualize multiple results before deciding. Schwartz et al. [29] asserted that increasing an individual's CL may broaden their perspective when making choices, such that goal-related implications are considered and enhanced self-control is exercised. Hence, we hypothesize that:

Hypothesis 2 (H2). *Students' CL in the Arduino course is positively related to their levels of LO.*

According to Chuang and Lee [8], students' CL in relation to goal-oriented activities can be changed with time and space in the context of learning. Liberman and Trop [25] proposed that, in goal-oriented activities, people with high CL are more concerned about the desirability of the final state of the activity and people with low CL are more concerned about the feasibility of the final state of the activity. Chuang and Lee [8] discovered that when students are faced with academic assignments of varying difficulty (feasibility) and attractiveness (desirability), students are more concerned about the attractiveness of the assignment when addressing a distant future assignment and are more concerned about the difficulty of the assignment when addressing an immediate assignment. Therefore, in the Arduino courses, the CL of the students was expected to affect the degree to which students' PA influenced their LO. Hence, we hypothesized that:

Hypothesis 3 (H3). *The CLs of students moderate the relationship between their PA and LO in Arduino courses.*

2.4. Role Ambiguity

Role ambiguity (RA) refers to the extent to which of a team member's responsibilities are not clarified as expected [30]. In this paper, RA is investigated as a potential moderator between PA and LO based on three factors: (a) the team-focused Arduino courses, (b) trends identified in previous literature, and (c) the guiding theory (role theory). First, because the team completes the tasks required by the Arduino course, RA may affect the correlation between PA and LO; this is because the degree of interdependence in the Arduino course requires students to rely on clear roles, responsibilities, and expectations when learning how to complete tasks. The perception of these roles is formed based on students' PA.

Second, previous research has suggested that RA can harm performance because it may impair an individual's ability to work and is associated with a sense of powerlessness and lack of control [31,32]. Therefore, evaluating the possibility of RA can promote an understanding of how programming skills negatively affect LO. Therefore, we hypothesize that:

Hypothesis 4 (H4). *Students' RA in the Arduino course is positively related to the level of LO.*

Finally, according to role theory, RA increases team members' demands and affects their views on roles and positions. RA reduces the clarity of information flow and overshadows expectations obtained from various sources, thus violating the purpose of role theory [31]. Individuals who are unsure of their position and status are unlikely to accept and participate in the promotion of interaction [30]. In the present study, the responsibilities and roles of students in the team were related to the students' initial PA required for the Arduino course. Therefore, when students participated in the Arduino course, if they were unsure about their positions in the team, the team was unlikely to promote interaction and reduced LO would thereby ensue. In addition, when different members of the team assume the same given roles and responsibilities, RA is more likely to occur [32]. This may exacerbate the uncertainty surrounding specific responsibilities because different team members may interpret these responsibilities differently. In conclusion, the degree of understanding of students' responsibilities and roles in the team will affect the influence of PA on LO. Therefore, we hypothesize that:

Hypothesis 5 (H5). *The degree of student RA moderates the relationship between their PA and LO in Arduino courses.*

3. Research Method

On the basis of the literature review, this study established a research model, as depicted in Figure 1.

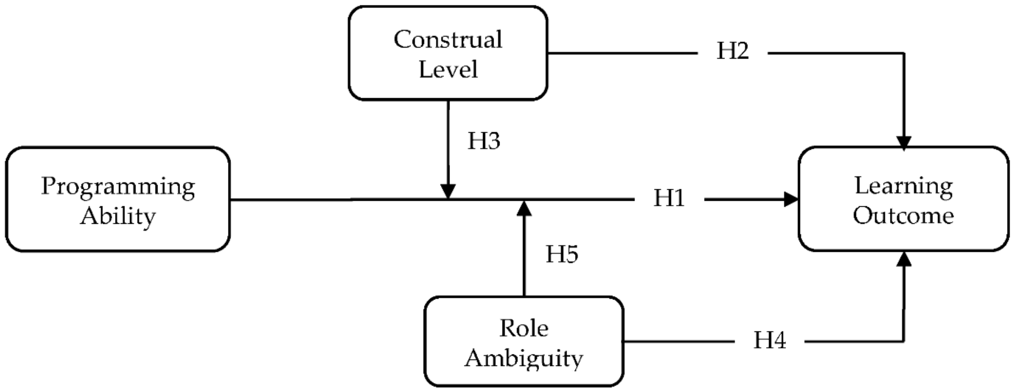

Figure 1. Research model and hypothesized relationships.

This research was conducted by an instructor at the teaching site without affecting teaching progress. Details of the research sample and procedure are described in the following sections.

3.1. Sample

This study was conducted at a junior high school in Central Taiwan; 161 students in the seventh grade participated, and among them, valid data were obtained for 157 students. At this school, an IT class was held once a week in a computer classroom; each student had access to a personal computer. Each participating student completed eight Scratch courses before taking the Arduino course, and each student's PA was assessed according to test results and general evaluations.

3.2. Operational Definitions of Research Constructs

3.2.1. Learning Outcome

After 4 weeks of Arduino course attendance, participants completed an online test designed by the teacher on the course content. This study defined an LO as the score that a participant obtained in this test.

3.2.2. Programming Ability

This study adopted the Scratch for Arduino approach. Before participating in this study, each participant completed eight Scratch programming courses that collectively constituted an introductory programming course. This study assessed participants' performance in Scratch according to their PA.

3.2.3. Construal Level

This study measured participants' psychological distance from the Arduino course and interpreted it as their CL [8]. Larger psychological distance from events results in a higher likelihood to conceptualize objects in an abstract manner (higher level) rather than in a specific manner (lower level) [23,33]. High-level goals are related to abstraction, and thus, the "why" aspect of an activity is associated with a high CL. Low-level goals are related to specificity, and thus, the "how" aspect of the activity in question is associated with a low CL. Therefore, participants' preference for the "why" or "how" aspects of the Arduino course indicated their CL.

3.2.4. Role Ambiguity

RA is defined as the extent to which the expectations of a team member's responsibilities are not clarified [30]. We defined RA as the participant's score after completing the questionnaire supplied in the work of Rezvani and Khosravi [30].

3.3. Procedure

The primary purpose of this study was to investigate how students' CL, PA, and RA affect their LO in an Arduino course. To test our hypotheses, the following experimental design was employed (see Figure 2).

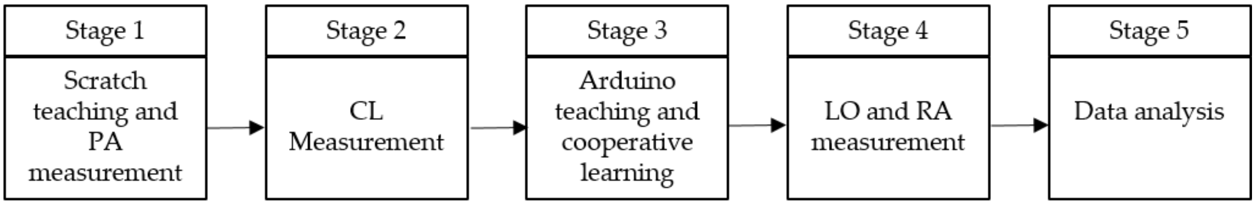

Figure 2. Research stages.

3.3.1. Stage 1

The first stage was the preparation work before the start of the Arduino course. Participants in this study participated in an 8-week (one class per week) Scratch course, which was part of the IT course in the course plan. When undertaking the Scratch course, students wrote a simulation program by observing the operation of traffic lights, including understanding the user interface of Scratch, basic grammar, repetitive structure, and process control. At the end of the course, participants completed a 10-question online quiz to assess their PA. The content of the test involved the example program created during the Scratch course study. The test assessed knowledge of the general Scratch program, its operation screen, process control, and use of repetitive structures.

3.3.2. Stage 2

Consistent with the work of Chuang and Lee [8], in the second stage, the participants were introduced to Arduino project-related videos and the use and composition of Arduino; thereby, the "why" and "how" of studying Arduino courses were explained. Participants were required to submit an experience report. The introduction covered their views on using Arduino for further learning, which may have led to different psychological distances. According to research by Liberman et al., students who are more psychologically distant from Arduino are more likely to conceptualize in an abstract manner (higher level) [23]. Conversely, students who are closer conceptualize it in a specific manner (lower level). Chuang and Lee [8] noted that, because higher-level goals are related to abstraction, the "why" aspect of the activity is related to higher CL. By contrast, lower-level goals are related to specificity, meaning that the "how" aspect of the activity in question is related to lower CL. Therefore, participants with higher CL tend to derive more abstract concepts, such as the vision and purpose of the activity. People with lower CL tend to derive specific concepts, such as the low-level goals and procedures involved in an activity.

This study proceeded in accordance with the works of Ho et al. [34] and Chuang and Lee [8]. The teacher first described two CL-oriented scenarios about an Arduino Bluetooth car. These scenarios included the "why" and "how" involved while remotely manipulating an Arduino Bluetooth car. Next, participants' CLs were evaluated. Under the guidance of teachers, students specified their preferences for "why" or "how" and "usefulness" or "ease of use". According to the medians of their responses, students were divided into high and low CL groups.

3.3.3. Stage 3

Stage 3 involved teaching participants how to use Arduino by using the Cooperative-Learning method [9,11,35] and GI model [16]. Participants were randomly divided into pairs, and each pair was issued a research questionnaire on the central theme. Each team was required to complete a common task (using Arduino to simulate the operation of traffic lights). The teacher emphasized the importance of teamwork before the task began and encouraged students to help each other as much as possible, actively assign roles and tasks, discuss, communicate, and complete tasks together. After the subthemes were outlined, the groups were free to assign investigation tasks. According to the content of the subthemes, teachers guided their respective participants to investigate the course content. After the groups completed the subtheme tasks, the teacher explained how to integrate the subthemes into the main theme. After each team submitted their work, the teacher reviewed and appraised it and asked each group to present their output to the class.

3.3.4. Stage 4

In stage 4, seven online questionnaires were used to survey participants' RA when undertaking the Arduino task; the survey items were adapted from those used by Rezvania et al. [30]. The degree of clarity that participants had regarding their responsibilities in the Arduino course work was assessed. Participants were urged to answer all question items. Questionnaires with incomplete answers were considered invalid.

At the conclusion of the Arduino course, the participants completed a 10-question online quiz to assess their LO. The content of the test was associated with the program example used during the Arduino course study. The test assessed knowledge of the Arduino program background, operation screen, process control, and use of repetitive structures.

3.3.5. Stage 5

Stage 5 comprised the data collation and analysis. Partial least squares (PLS) analysis was performed to explore the relationship among PA, CL, RA, and LO. After data analysis, the proposed hypotheses were tested, and conclusions were drawn.

4. Data Analysis and Results

4.1. Sample Demographic

Valid responses were collected from 157 students, of which 80 were boys and 77 were girls. For the PA test, the lowest score was 10 points, the highest score was 100 points, and the average score was 56.815 points. The LO test result had a minimum score of 1 point, a maximum score of 5 points, and an average score of 2.955 points.

4.2. Reliability and Validity of the Measurement

The measurement analysis results are summarized in Table 1. The factor loading scores of the RA and CL items were greater than 0.77, indicating that the RA and CL constructs of this experiment had sufficient convergent validity. Regarding reliability, the questionnaire had a Cronbach's α greater than 0.78, indicating that the RA and CL constructs investigated in this study had sufficient reliability.

Table 1. Summary of the RA and CL scale.

Construct (Source)	Item	Mean	Standard Deviation	Factor Loading	Cronbach's α
RA [30] *	1. My authority (degree of freedom) matches the responsibilities assigned to the job.	2.669	0.9766	0.771	0.892
	2. My responsibilities in the group are clear.	3.013	0.9336	0.848	
	3. I am clear about how much authority (degree of freedom) I have in this group.	2.860	1.0406	0.780	
	4. My work in this group has clear goals in terms of planning.	2.777	1.0165	0.820	
	5. In this group, I know what is expected of me.	2.650	1.0431	0.773	
	6. In this group, I know what my responsibilities are.	3.083	0.9196	0.858	
CL [8]	1. When completing technology-related courses, such as the Arduino Bluetooth self-propelled car, I am more concerned with "why" we study such courses, rather than "how" to study them.	2.484	1.0537	0.850	0.780
	2. For me, when studying technology-related courses, "achieving goals" is more important than learning "how to learn".	2.465	1.0654	0.828	
	3. When studying technology-related courses, I care more about whether it is "useful" for my future learning rather than how to make learning "easier".	2.777	1.0537	0.823	

* Note: This part is reverse coded.

4.3. Hypothesis Testing

This study used structural equation models (SEMs) to evaluate the parameters and test the hypotheses of the proposed causal model. According to Hair Jr et al. [36], the component-based SEM (PLS-SEM; e.g., SmartPLS) has higher predictive ability than the covariance-based SEM does; therefore, it is more suitable for theoretical development in the initial exploration stage [37]. In addition, PLS-SEM is more suitable for a study with a small sample size [36]. Therefore, this study adopted SmartPLS and is used for hypothesis testing, and results are shown as follows.

First, according to Table 2, PA had a significant effect on LO ($\beta = 0.470$, $p < 0.01$), so H1 was supported. Second, CL ($p > 0.1$) had no significant effect on LO, so H2 was not supported. Third, although CL had no significant effect on LO, we discovered that CL had a significant negative moderating effect on the relationship between PA and LO ($p < 0.05$), so H3 was supported. Fourth, RA had a significant effect on LO ($\beta = -0.164$, $p < 0.05$), so H4 was supported. Finally, we identified that RA did not moderate the relationship between PA and LO, so H5 was not supported. These results are summarized and displayed in Figure 3.

Table 2. Summary of the hypotheses test results.

Path	Standardized Path Coefficient	*t*-Value	Supported
H1: PA -> LO	0.470	6.252 ***	Yes
H2: CL -> LO	−0.023	0.287	No
H3: PA * CL -> LO	−0.212	3.234 **	Yes
H4: RA -> LO	−0164	2.474 **	Yes
H5: PA*RA -> LO	−0.051	0.89	No

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

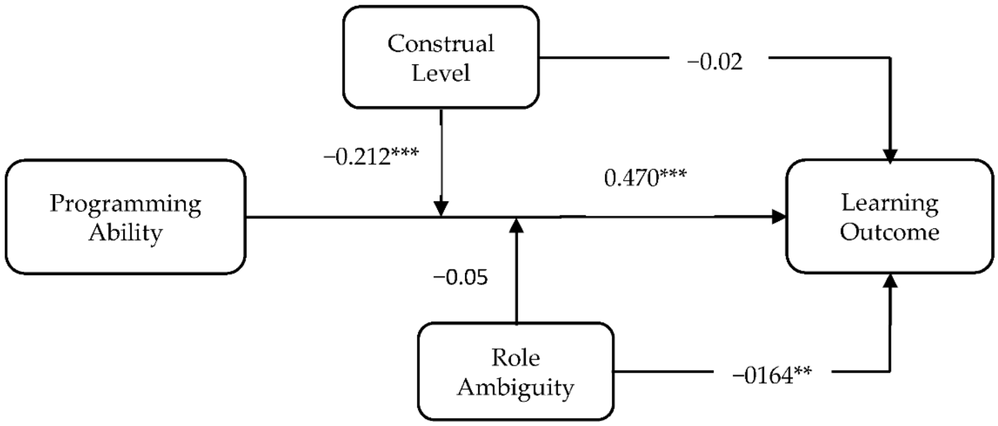

Figure 3. Research model and PLS analysis results. ** $p < 0.05$, *** $p < 0.01$.

5. Conclusions and Discussion

5.1. Conclusions

Computer programming has been re-emphasized in curriculum planning in the past decade, creating changes in not only learning program designs but also in a renewed commitment to prepare students for the future. In this study, we discovered that, through careful arrangement of course content and teaching, PA (measured by Scratch learning performance) demonstrates a significant positive effect on the learning effectiveness of the Arduino course. This result is consistent with the expectation that participants with stronger initial PAs will have higher LOs. Therefore, in addition to affirming the practicality of the Scratch for Arduino approach, this study confirmed the importance of basic programming capabilities.

In addition, CL exhibited no significant effect on LO. This result differs from that of the study conducted by Chuang and Lee [8]. Thus, CL can affect the satisfaction of participants when learning science and technology courses, but it has no significant effect on final learning achievements. Nevertheless, CL has a negative moderating effect on the effect of PA on LO. This result is consistent with that of Chuang and Lee [8]. For students with high CLs, PA and LO decreased; conversely, for students with a low CL, PA and LO increased. A possible reason is that students with a high CL originally had higher expectations for psychologically distant goals, but as the CL associated with the learning process turned from a focus on idealism to feasibility, learning satisfaction and LO were reduced. In contrast, students with low CL obtained stable and improved learning satisfaction and LO because they continually improved their PA.

The research results indicate that RA has a negative effect on LO. In other words, when students study a science and technology course, RA will affect their learning achievement. The less clear participants are about their role during course work, the lower their learning achievement is. In addition, PA has a significant effect on LO, but it does not interfere with the extent of that effect because participants are unaware of role positioning. Leo et al. [38] investigated how players' understanding of RA, role conflict, team conflict, and team cohesion explains their collective effectiveness in the team, arguing that RA and role conflict are insufficient to explain changes in collective efficacy. They further noted that, although some studies have found a positive correlation between RA and role effectiveness, these variables relate to individuals' perceptions of their behavior and not to group variables, such as collective effectiveness. A player's perceptions of RA or role conflict have no group dimension because both refer only to the player in question (i.e., how well he or she understands the required functions). Therefore, we contend that because this research focuses on the learning process and performance at the individual level and the teaching activities are designed as task- or goal-oriented learning activities, the moderating effect of RA on the PA–LO relationship is reduced. In other words, in this study, the GI method in cooperative learning was used for teaching in the field of science and technology, and the degree of PA's influence on LO was unaltered because of students' personal RA.

Popat and Starkey [39] argued that curriculum and pedagogy influence the range of skills learned when studying coding. In addition, Shachar and Fischer [16] examined the effects of the GI method of cooperative learning on participants' academic achievement, motivation, and perceptions of their experience, discovering that the usually average- and low-achieving participants in the GI classes achieved higher scores, whereas motivation declined in the experimental group compared with the control group. Therefore, in the teaching of programming-related courses, the use of GI in cooperative learning can improve learning performance; hence, we suggest that this method is an effective choice for teaching science and technology courses.

5.2. Theoretical Implications

The CL and role theories in psychology-related fields are of relatively limited application in technology-oriented programming teaching. The results of this innovative research confirm the applicability and benefits of considering such theories in designing and implementing computer programming courses. In addition, this research confirms that applying the GI of cooperative learning and manipulating the degree of learners' CL can effectively enhance their LO. This finding is consistent with the conclusions of Chuang and Lee [8], and the present study suggests that the degree of CL negatively moderates the relationship between PA and LO. However, Chuang and Lee [8] reported that the degree of CL has a significant positive influence on learning satisfaction; nevertheless, CL was not correlated with the LO, which means that there is a gap between learning satisfaction and learning outcome [8]. Therefore, students require a topic-oriented approach to guide their learning.

This research also confirms that, through appropriate curriculum planning, goal-oriented learning projects, and guiding the division of labor and cooperation in group interaction, the adverse effects of RA can be avoided. Therefore, GI of cooperative learning can improve students' problem-solving skills in the context of programming course delivery, thereby providing students with opportunities for benchmarking. Thus, using these methods, educators can strive to improve student learning effectiveness and further the greater educational goals and benefits of learning with programming.

The RA not exerting the expected adjustment effect exemplifies the concepts that Bagger and Li [40] called result-oriented "performance goals" and process-oriented "learning goals". These arguments suggest that learning-oriented individuals will actively seek information that can reduce the ambiguity of their role, and even if they fail to do so, they can seize the opportunity to improve their personal abilities. These qualities allow them to maintain flexibility and positive thinking even in the most challenging situations and simultaneously overcome ambiguity in their roles to perform tasks effectively. Because the curriculum content and teaching methods are properly designed to promote students' learning goal orientation, RA has no negative effect on the relationship between programming ability and LO.

Finally, the findings of this research accord with the argument of Popat and Starkey [39], who contended that, although students learn programming in the classroom, in the process, students can learn or practice many other critical skills at the same time, such as problem-solving, critical thinking, social, self-management, and academic skills.

5.3. Managerial Implications

In the era of the information economy, the importance of artificial intelligence-related technologies are gaining more and more value and programming courses are becoming ever more crucial. The learning achievements derived from computer programming courses has become a key concern. This study explored the relationship between PA, CL, RA, and LO. The research findings can provide some practical suggestions for computer programming course delivery. First, because of the positive relationship between PA and

LO, teachers must attach importance to developing students' basic PA and arrange course content and teaching methods in a gradual fashion. Second, because the degree of CL has a significant negative moderating effect between PA and LO, teachers can plan challenging main objectives in practical projects, as well as multiple secondary goals to maintain the learning motivation and LO of students with high PAs. Third, because RA has a significant negative effect on LO, teachers can intermittently intervene to guide group interactions in the context of cooperative learning to ensure a clear division of labor and improve group performance. Finally, this study discovered that although RA negatively affects LO, it does not play a moderating role. A clear division of labor and an appropriate number of people, such as GI, can effectively nullify the negative impact of RA.

5.4. Limitations and Directions for Future Research

Although we strove for perfection in this research, notable limitations remained. First, because the research was of an experimental nature and the number of samples relatively limited, follow-up research can adopt a large-sample questionnaire survey to enhance the applicability of the conclusions. Second, the teaching content of this study was mainly based on the Arduino application, including programming and line assembly, which differs from other teaching tools; hence, the broader applicability of the conclusions drawn may be limited. Third, this study does not consider students' personal characteristics, such as self-learning levels; future studies can explore the influence of critical personal traits. Fourth, similarly, this study focused on RA in the context of group interactions; future studies can assess the effect of other group traits, such as interpersonal interaction intelligence, on LO. Finally, in programming courses, the use of programming interfaces may affect students' acceptance and concentration, and further studies can consider the impact of varied teaching content and methods on LO.

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