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EFFECTS OF GLOBAL VERSUS LOCAL PARTNERSHIP ON STUDENTS' COLLABORATIVE PROBLEM-SOLVING AND IMAGINATIVE CAPABILITIES

Kuen-Yi Lin*
National Taiwan Normal University

Yi-Ting Hsu
Chien-Kuo Junior High School

Walter S. Smith
Texas Tech University

Thalia Micklewhite
The University of the Bahamas

Tarah McDonald
The University of The Bahamas

Abstract: *This research investigated the effectiveness of global partnerships in developing participants' collaborative problem-solving and imaginative capabilities and helping them acquire the critical skills necessary in the 21st century. To achieve this aim, a quasi-experimental, nonequivalent group pre-test, post-test design was primarily adopted. This design was used to conduct a teaching experiment among 47 global partnership members from the United States and The Bahamas, and 24 students from Taiwan. An analysis of covariance and the Johnson-Neyman procedure were used to examine the actual effectiveness of global partnerships. Two main conclusions were drawn: (a) the global partnership members demonstrated poorer collaborative problem-solving and imaginative performances than the local partnership team; (b) the main difficulties encountered by the global partnership team included language barriers and the inability to establish cognitive-based trust.*

Keywords: *balloon car, collaborative problem solving, global partnership, local partnership, imaginative capabilities*

* Corresponding Author (linkuenyi@ntnu.edu.tw)
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INTRODUCTION

In a world with multi-national teams, many business needs are not fulfilled through independent problem-solving tactics. Instead, they have placed more emphasis on leveraging collaborative internet technologies to achieve teamwork based on problem solving. At a minimum, the advantages of teamwork are effective division of labour; integration of diverse information, including different knowledge, perspectives, and experiences; and improved solution quality through team members' support (Kopp et al., 2014; Sang et al., 2018). With curriculum reforms, countries like Singapore and Israel have shown concern regarding the critical skills that their nationals should acquire in the 21st century, including collaborative problem-solving skills (Darling-Hammond, 2011). Oftentimes, prior research related to the development of collaborative problem-solving skills focused on team members from the same cultural background. For instance, Vass (2007) focused on exploring the effects of collaborative partners' design on children's creative writing performances, and the results showed that the collaborative partners can stimulate and improve their creative writing performances by using the same language and culture.

But for international or global enterprises, the essence of teamwork is to bring together cross-cultural and cross-border teams to communicate and solve problems in cyberspace rather than share only mutual time and space in pursuit of the enterprises' goals or solving practical problems. Therefore, the difference in collaborative problem-solving capabilities between a global partnership team made up of people with varying cultural backgrounds and a local partnership team made up of people with the same cultural background is a major topic worth exploring. Jones and Oberst (2000) as well as Jones et al. (2002) offered international cooperation experiences for engineering students by distance learning technology due to the extremely small number of them working and studying abroad. The research also showed that virtual global partnership experience had been already provided in some engineering schools in the United States, and that this not only helped students to gain easy access to opportunities for international collaboration, but also increased the chances of success. As a result, multi-national team members could benefit from collaborative creative thinking and solve problems through brainstorming together. Furthermore, Herro et al. (2017) conducted research on middle school students from different states in the United States in order to examine their collaborative problem-solving performances during STEAM activities, so as to understand how they exchanged professional knowledge and discussed the solutions repeatedly as they worked together.

This research focused on exploring if a global partnership team made up of people with different cultural backgrounds could improve their collaborative problem-solving skills, communication skills and imagination while dealing with practical difficulties.

Global partnership teams may encounter more difficulties during collaborative problem solving due to their different cultural backgrounds (Angeli & Schwartz, 2016). However, whether such differences collide and spark the team's imagination is another key subject in this research. Grossen (2008) noted that when proposing initial ideas, proper communication, and coordination among team members with different cultural backgrounds can stimulate their imagination and help them generate innovative ideas. This is especially true with team members from different social and institutional backgrounds. Teamwork in this environment can improve their creativity and evoke more novel ideas if they can reach a consensus through communication. In addition, Hoever et al. (2012) found that, compared with team members from the same cultural background, those with different backgrounds displayed more creativity. This research therefore explored also how to effectively mediate emotional conflicts and different opinions among global team members.

In summary, this research mainly focused on comparing the differences in collaborative problem-solving and imaginative capabilities between global and local partnership teams when faced with problem-solving tasks. It aimed at proposing related suggestions as a reference for the development of critical skills required of students in the future. The research questions are as follows:

1. How effective are global partnerships in developing students' collaborative problem-solving capabilities compared to local partnerships?

2. How effective are global partnerships in developing students' imaginative capabilities as compared to local partnership?

3. For educators' future reference, what suggestions may be made for using global partnerships to develop students' collaborative problem-solving and imaginative capabilities through problem-solving tasks?

THEORETICAL FRAMEWORK

Global Partnership and Collaborative Problem Solving

Our goal is to put emphasis on the establishment of shared understanding in collaborative problem solving. Therefore, collaborative discussion and imaginative thinking during classes is our focus. In the collaborative problem-solving framework put forth by the Organization for Economic Co-operation and Development (2013), collaborative problem-solving capabilities comprise mainly three aspects: (a) establishing and maintaining shared understanding, (b) taking appropriate action to solve the problem, and (c) establishing and maintaining team organization. There have been a few studies related to the benefits of global partnerships in collaborative problem solving. For example, Heller and Hollabaugh (1992) believed that the group size, gender, and ability composition of global partnership teams contribute to the problem-solving performance of collaborative groups. Hmelo-Silver (2004) also argued that the heterogeneity within global collaborative groups can help students apply their knowledge to problem-solving tasks. As a result, they can identify solutions effectively, while reflecting on and internalizing the knowledge they have gained.

Nevertheless, further discussion on the three types of collaborative problem-solving capabilities proposed by the Organization for Economic Co-operation and Development (2013) reveals many corresponding difficulties and issues with global partnerships that need to be overcome. First, in terms of establishing and maintaining shared understanding, Jarvenpaa and Leidner (1998) suggested that global partnerships can achieve short-term trust through the Internet. However, factors like language barriers, cultural diversity, geographical dispersion, and inconsistency with Internet communication time make it difficult for global team members to establish a cognitive and emotional basis for trust. These difficulties easily lead to incomplete trust within global teams. As such, they are unable to establish and maintain high levels of shared understanding.

West and Anderson (1996) also proposed that during the stage of establishing and maintaining shared understanding, language-related restrictions may affect how global teams interpret articulated ideas. As ideas are proposed, developed, and implemented, these factors may either hinder or facilitate the expression of appropriate ideas. Members may even fail to interact effectively and make mutual decisions at critical moments. On the other hand, Cohen and Gibson (2003) argued that, during global partnership projects, team members may face greater difficulties in building a harmonious work environment and maintaining shared understanding due to their geographical and environmental differences.

Therefore, it is important for global partnership teams to address how they should overcome language and cultural barriers in order to establish an emotional basis for trust and establish or maintain shared understanding.

As for taking appropriate action to solve the problem, McLeod and Lobel (1992) suggested that global teams can be defined as heterogeneous groups in terms of their member composition. Therefore, compared with homogeneous groups, global teams have more room to stimulate creativity and reinforce thinking, in turn producing high-quality solutions through brainstorming. In addition, global teams' cross-disciplinary work design can promote communication and interaction among members with different specialties, thereby facilitating the tasks of team-based problem solving (Parker, 1994; Mohrman et al., 1995). Van de Bossche et al. (2006) held similar views in that they believed that due to the members' different social cognition processes, global partnerships can produce better team performance by facilitating knowledge construction and helping members propose appropriate solutions. Therefore, if global teams can leverage the different members' characteristics and effectively interact and exchange knowledge, they should be able to deliver better performance when it comes to taking appropriate actions to solve problems.

In terms of establishing and maintaining team organization, Wiersema and Bantel (1992) suggested that similarities among team members are beneficial to achieving a higher level of team consensus and proper communication. Teams which have members with similar characteristics can more easily solve problems using innovative approaches. According to Jarvenpaa and Leidner (1998), as global team members rely on the Internet for communication, it is difficult for them to establish emotional bonds and trust. Given the lack of a cognitive and affective basis, they are unable to easily develop trust, recognize one another, and maintain team organization. Thus, global teams must determine how to establish a stable cognitive and affective basis and maintain team organization among members.

Based on previous analysis and discussion, it is hard for the global team members in overcoming language and cultural barriers to establish an emotional basis of trust (Cohen & Gibson, 2003) and maintain team organization among members (Jarvenpaa & Leidner, 1998). The research formulated suitable strategies (e.g., regular meetings, doing hands-on activity together) to improve global partnerships and also try to explore the differences between collaborative problem-solving performances between a global team and a local team.

Global Partnership and Imaginative Capabilities

Imagination is mainly defined as "a creative faculty" or "a power of the mind" (Perdue, 2003). Imagination is also defined by many contemporary psychologists as an advanced psychological function primarily because it involves mental construction of integrated memories and experiences. As opposed to addressing past or present perceived realities, imagination is used to predict future reality (Morosini, 2010). To measure imagination effectively, this research mainly adopted the imaginative capability scale (ICS) developed by Liang and Chia (2014) using exploratory and confirmatory factor analyses.

ICS classifies imagination into three capability aspects:

(a) initiating imagination, which mainly refers to the imaginative ability to originate novel, ground-breaking ideas through exploration, and consequently generate a rich diversity of ideas; it includes the indicators of exploration, novelty, and productivity.

(b) conceiving imagination, which is mainly defined as an individual's ability to formulate effective ideas to achieve a specific goal by concentrating on and constantly revising ideas when faced with problems; it includes the five indicators of effectiveness, dialectics, sensibility, intuition and concentration.

(c) transforming imagination, which is mainly the ability to crystallize imagination, transform existing experiences, and put them into practice; it includes the indicators of crystallization and transformation.

Based on a further exploration of the three imagination aspects proposed by Liang and Chia (2014), current research achievements related to global partnerships and imagination can be summarized as follows. First, in terms of initiating imagination, studies on brainstorming discovered that multi-ethnic teams produce higher-quality ideas, and those global teams can produce more diverse alternatives when searching for solutions (Watson et al., 1993). Milliken and Martins (1996) found that in a global team that is more heterogeneous, the membership has more sensitive emotional reactions to the imaginative contents. As a result, their imaginative capabilities are more intensely elicited, and they can initiate more diverse ideas. Egan (2005) noted that heterogeneous groups can produce highly imaginative viewpoints when faced with complicated tasks, while Shin et al. (2012) investigated three business teams from different cultural backgrounds and found that global partnerships are

effective in improving members' imagination and self-efficacy. Therefore, the heterogeneity of global teams should improve members' performance in initiating imagination.

In terms of conceiving imagination, Earely and Mosakowski (2000) conducted research on five global teams specializing in product development and sales. The results indicated that the global team members could concentrate on discussing imaginative topics for longer periods without becoming distracted. They could also express abstract ideas with concrete images, consequently formulating the appropriate practical solutions to achieve the ultimate goal of solving problems. Basadur (2004) believed that as global team members have varying means to form conceiving imagination, the key factor that affects their future performance is how they coordinate and integrate their different styles. Meanwhile, Barczak et al. (2010) also suggested that global teamwork can strengthen team imagination and produce satisfactory imaginative content as they develop cognitive trust, establish shared statements, and integrate problems. This in turn enhances the members' ability to create and share knowledge. Therefore, if global teams can properly develop cognitive trust and establish shared understanding, it means that they can generate satisfactory imaginative contents. In other words, they should be able to perform well in terms of conceiving imagination.

With respect to transforming imagination, Stempfle and Badke-Schaub (2002) integrated design thinking into global teams. Through the guidance of such design thinking, they discovered that global team members can transform different messages into imaginative content and consequently propose solutions by consensus. Hannaford (2012) studied a global team of children from different cultural backgrounds and found that members with different experiences would stimulate one another's output of views. The team members were good at repeatedly correcting their imaginative contents and proposing valuable insights to achieve mutual cognition or uniform ideas within the team. Hence, integrating appropriate collaborative strategies into global partnerships should stimulate team members' performance in transforming imagination, thus helping them propose unique solutions.

Based on previous analysis and discussion, we argue that global team members can have better performances in imaginative capabilities if they could establish an emotional basis of trust (Cohen & Gibson, 2003) and maintain team organization among members (Jarvenpaa & Leidner, 1998). In more heterogeneous global teams with greater differences in the members' backgrounds, team members can more fully express their opinions and thoughts. Within the open education atmosphere, brainstorming and, hence, the practice of their imagination are facilitated. Meanwhile, the major focus of this research is on how to stimulate the imaginative capabilities of global team members by setting goals and

integrating collaborative strategies. The research formulated suitable strategies (e.g., creative thing strategy in stimulating students' creative ideas) to stimulate students' imaginative capabilities and also to try to explore the differences between the imaginative capabilities of a global team and those of a local team.

METHODOLOGY

Research Design

This research mainly adopted a quasi-experimental, nonequivalent group pre-test, post-test design as shown in Table 1. To explore the effectiveness of global partnerships in developing learners' collaborative problem-solving and imaginative capabilities, global partnership teams with members from the United States, The Bahamas, and Taiwan were considered the experimental group, while the local partnership teams from Taiwan constituted the control group. The pre-test was conducted using a collaborative problem-solving capability scale and the ICS to eliminate prior differences in the learners' collaborative problem-solving and imaginative capabilities. Conversely, the post-test was conducted with a copy of both scales to determine the global partnership's effectiveness in developing students' collaborative problem-solving and imaginative capabilities.

Table 1
Research design

Group	Pre-test	Experiment	Post-test
Experimental	Collaborative problem-solving capability scale ICS	Global partnership	Copy of collaborative problem-solving capability scale Copy of ICS
Control	Collaborative problem-solving capability scale ICS	Local partnership	Copy of collaborative problem-solving capability scale Copy of ICS

Note. The collaborative problem-solving capability scale and ICS used in the post-test were both copies. The statement order was adjusted, but the contents were not changed.

Research Targets

The targets for this research were teachers or student teachers in the technologies, sciences, engineering, and mathematics fields. A total of 78 students from the United States, The Bahamas, and Taiwan were enrolled and distributed across 17 global teams for the experimental group. There was at least one student from each country in each team in the experimental group, and the rest of the students were distributed among different teams at random. However, only 47 students finished the measurement of collaborative problem-solving skills and imaginative capabilities. Another 24 students from Taiwan were also

evenly distributed across six teams for the control group. There were four students for each team in the control group.

The instructional objective of the technology class in this research includes teaching students to apply STEM on (a) designing and making of a balloon car, (b) developing positive technology literacy, and (c) being familiarized with the process of design and making. Furthermore, students had to coordinate with researchers so that possible threats, (e.g. the collaborative problem-solving process, the materials of the balloon-powered car), could be reduced as much as possible in order to ensure the internal validity of the research design. The problem-solving task assigned to both the experimental and the control group was to design and make a balloon car that must be able to travel at least five metres on a one-metre-wide track – the farther, the better. Table 2 indicates the gender and nationality composition of the research subjects. The teaching experiment was jointly designed by researchers from the United States and Taiwan, who had undertaken meticulous planning in advance regarding the overall activity arrangements and design. Any variable that might affect the experimental teaching (such as the teachers' instructional approaches and the students' participation frequency in the online discussion course) were controlled to the maximum extent to ensure the internal validity of the research design.

Table 2

Summary of descriptive statistics of the research targets

Group	Gender		Nationality		
	Male	Female	The U.S.	Bahamas	Taiwan
Control	11	13	0	0	24
Experimental	7	40	19	16	12

Research Implementation

Materials and tools were well prepared by students in the activity. Students were required to finish the design and making of balloon-powered cars by using materials and tools regulated by the researchers. The listing of the type and quantity is shown in the following tables 3 and 4 and Figure 1. Teachers were encouraged to design the curriculum according to students' ability.

Table3

Materials list

Name	Quantity
Balloons	2 pcs
Rubber Bands	4 pcs
Corrugated Boards	2 pcs
Thick Straws	2 pcs
Fine Straws	2 pcs
Sticks	2 pcs

Note. In units of groups.

Figure 1

Example of materials

Table 4
Tool lists

Tools	Number
Scissors	1 pc
Box Cutter	1 pc
Glue Gun	1 pc
Hot Glue	Several pcs
Tape	1 pc
Ruler	1 pc

Different types of balloon cars could be made with the materials and tools provided above. The making steps shown in the following table are mainly examples of commonly used balloon cars. Development of problem-solving skills and imagination stimulation in each step is also included. The following steps were only for the reference of teachers. When the actual course was implemented, students could freely use other materials for design and making.

Table 5
Procedures for making a balloon car

	Design and Making Steps	Students' Activity
Step 1	Draw a design sketch according to restriction.	1. The team confirms the task content of the balloon car activity (objectives, resources, constraints, etc.) 2. After the discussion, the team draws out several preliminary conceptual designs, considers possible problems and selects the final plan
Step 2	Select suitable materials according to the design drawings.	1. The team uses creativity and imagination to choose lightweight, solid materials
Step 3	Determine the size and position of the car body and wheel to make the car.	1. The team proposes problem-solving approaches to increase car stability by applying their STEM knowledge

		2. The team proposes problem-solving approaches to reduce car resistance by applying their STEM knowledge
Step 4	Use straws and sticks as axles to fix on car body.	1. The team pays attention to whether the car body affects the smoothness of the wheels when rolling
Step 5	Install wheels and secure balloon.	1. The team brainstorms to analyse the key design points, such as the centre of gravity of the balloon car, the symmetry of the car body, etc.
Step 6	Test according to rules.	1. The team works to solve the problem that the car deviates from the track to the left or right when moving forward
		2. The team works to solve the problem of the car shaking and overturning in the activity

The implementation period was from October to November 2016. The problem-solving task of designing and making a balloon car (as per the reference model shown in Figure 2) was primarily in accordance with suggestions by Stempfle and Badke-Schaub (2002). Both the global and local teams were guided by a problem-solving learning procedure to assist students in the processes for effective goal-setting, management control, design amendments and adjustments, and model making. The main design for both groups' teaching activities is illustrated in Table 6.

Table 6

Description of teaching activities

Week	Global Partnership Team	Local Partnership Team
1	● Measuring collaborative problem-solving and imaginative capabilities ● Introducing the balloon car activity ● Connecting global team members and establishing a communication channel	● Measuring collaborative problem-solving and imaginative capabilities ● Introducing the balloon car activity
2	● Defining the problem (Skype) ● Proposing initial ideas (Skype)	● Defining the problem (face to face) ● Proposing initial ideas (face to face)
3	● Collecting and sharing information (Skype)	● Collecting and sharing information (face to face)

	● Discussing the concrete design (Skype)	● Discussing the concrete design (face to face)
4	● Designing and making the balloon car (Skype)	● Designing and making the balloon car (face to face)
	● Displaying the completed car (Skype)	● Displaying the completed car (face to face)
5	● Conducting reviews, self-reflections, and improvement (Skype)	● Conducting reviews, self-reflections, and improvement (face to face)
	● Proposing the optimal design (Skype)	● Proposing the optimal design (face to face)
6	● Measuring collaborative problem-solving and imaginative capabilities (scale copies)	● Measuring collaborative problem-solving and imaginative capabilities (scale copies)

Figure 2

The Exemplar of the balloon car

Research Tools

Collaborative Problem-solving Capability Scale. With increased complexity and problem uncertainty, Program for International Student Assessment (PISA) is used to evaluate capability of collaborative problem solving. The researchers used the collaborative problem-solving capability scale as shown in Table 7 to evaluate the teams'

collaborative problem-solving capability. The use of this scale was based on the following problem-solving processes and competencies proposed by the Organization for Economic Cooperation and Development (2013). The four problem-solving processes were: "exploring and understanding", "representing and formulating", "planning and executing" and "monitoring and reflecting". The three collaborative problem-solving competencies were: "establishing and maintaining shared understanding", "taking appropriate action to solve the problem" and "establishing and maintaining team organization". These factors were interwoven to form 12 collaborative problem-solving capability indicators that were used as the main scale items. A six-point scale was adopted for the students to review and evaluate themselves.

Table 7

Collborative problem-solving capability assessment matrix

Skills Process	(1) Establishing and maintaining shared understanding	(2) Taking appropriate action to solve the problem	(3) Establishing and maintaining team organization
(A) Exploring and Understanding	(A1) Discovering perspectives and abilities of team members	(A2) Discovering the types of collaborative interaction needed to solve the problem, along with the goals	(A3) Understanding roles to solve the problem
(B) Representing and Formulating	(B1) Building a shared representation and negotiating the meaning of the problem	(B2) Identifying and describing tasks to be completed	(B3) Describing roles and team organization (communication protocols/rules of engagement)
(C) Planning and Executing	(C1) Communicating with team members about the actions to be/ being performed	(C2) Enacting plans	(C3) Following rules of engagement, (e.g., prompting other team members to perform their tasks)
(D)Monitoring and Reflecting	(D1) Monitoring and repairing the shared understanding	(D2) Monitoring results of actions and evaluating success in solving the problem	(D3) Monitoring, providing feedback, and adapting team organization and roles

Source: Organization for Economic Cooperation and Developmentm, 2013, p. 11.

Imaginative Capability Scale. The ICS used in this research was the one devised by Liang and Chia (2014). It consisted mainly of three aspects: initiating imagination, conceiving imagination, and transforming imagination. Initiating imagination included three indicators – exploration, novelty and productivity – which accounted for nine items. Conceiving imagination involved five indicators – effectiveness, dialectics, sensibility, intuition, and concentration – which constituted 12 items. Transforming imagination included two indicators – crystallization and transformation – which constituted eight items. The scale employed a 6-point design and was shown to have satisfactory reliability and validity upon complete exploratory and confirmatory factor analyses. It was already published in the *Creativity Research Journal* (Liang and Chia, 2014).

Information Analysis and Interpretation

Analysis of covariance (ANCOVA) was primarily adopted to investigate the effectiveness of global partnerships in developing students' collaborative problem-solving and imaginative capabilities. The pre-test scores for collaborative problem-solving and imaginative capabilities were used as a covariate to eliminate the students' inherent differences in collaborative problem-solving and imaginative capabilities. Analysis of this quantitative data could shed light on the effectiveness of global partnerships in developing students' collaborative problem-solving and imaginative capabilities. On the other hand, during ANCOVA, homogeneity tests of within-group regression coefficients might show a violation of the assumption of homogeneity. Therefore, this research referred to the suggestions by Ji (2016) and adopted the Johnson-Neyman procedure for analysis to avoid statistical errors arising from the inability to remove the effects of the covariate due to the direct use of observed scores.

RESULTS

Effects of Global Partnerships on Collaborative Problem Solving

In terms of the overall collaborative problem-solving performances by the global and local teams, analytical results in Table 4 indicate that the post-test mean scores of the local and global teams respectively were 7.71 and 4.05 higher than their respective pre-test mean scores. Before the teaching experiment, the collaborative problem-solving capabilities of the global team students (M=57.40, SD=10.86) outshone those of the local team students (M=54.33, SD=11.78). However, after the experiment, the collaborative problem-solving capabilities of the local team (M=62.04, SD=9.78) surpassed those of the global team

(M=61.09, SD=10.66). Despite this, as such data analysis did not exclude the students' basic differences in collaborative problem-solving capabilities, ANCOVA was adopted to determine the actual effectiveness of global partnerships in developing such capabilities.

Table 8
Analysis of participants' collaborative problem solving

Items	*Global partnership* (*N*=47)		*Local partnership* (*N*=24)	
	M	*SD*	*M*	*SD*
Pre-test: Collaborative Problem Solving				
1. Establishing and maintaining shared understanding (4)	17.72	3.62	17.04	3.77
2. Taking appropriate action to solve the problem (4)	22.04	4.44	21.13	4.69
3. Establishing and maintaining team organization (4)	17.64	3.67	16.17	3.80
Sum (12)	57.40	10.86	54.33	11.78
Post-test: Collaborative Problem Solving				
1. Establishing and maintaining shared understanding (4)	18.43	3.25	19.83	2.66
2. Taking appropriate action to solve the problem (4)	23.77	4.46	23.21	4.20
3. Establishing and maintaining team organization (4)	18.89	3.59	19.00	3.32
Sum (12)	61.09	10.66	62.04	9.78

Before ANCOVA, it was necessary to first test whether results in different aspects of the collaborative problem-solving capability scale matched the assumption of homogeneity of within-group regression coefficients. Among the four aspects of "establishing and maintaining shared understanding" (F=0.36, p=0.55), "taking appropriate action to solve the problem" (F=4.58, p=0.04), "establishing and maintaining team organization" (F=3.52, p=0.07), and the overall collaborative problem-solving (F=3.31, p=0.07), all aspects, excluding "taking appropriate action to solve the problem", were found to comply with the assumption of homogeneity. Hence, these three aspects could be examined by ANCOVA,

whereas the scores for "taking appropriate action to solve the problem" were analysed and compared using the Johnson-Neyman procedure.

Table 9 presents the ANCOVA results of items that matched the basic assumption of homogeneity of within-group regression coefficients. One aspect yielded statistically significant results in terms of inter-group effect: "establishing and maintaining shared understanding", with F (1, 68) = 6.52 and an effect size of 0.09. According to the suggestions made by Cohen (1988), this experimental effect size was considered small. In other words, there was a significant difference between the mean scores of the global and local teams in terms of "establishing and maintaining shared understanding". After removing the pre-test factor for this aspect, their performances in "establishing and maintaining shared understanding" demonstrated a difference that represented a small effect size. Furthermore, the adjusted post-test mean scores for the local team (control group) and the global team (experimental group) were respectively 20.03 (with a SD of 0.54) and 18.33 (with a SD of 0.39). This indicated that, compared with global partnerships, local partnerships are more effective in enhancing students' performance in establishing and maintaining shared understanding.

Table 9

ANCOVA results for collaborative problem solving in different groups

Source	*SS*	*df*	*MS*	*F*	η^2
Collaborative Problem Solving					
Treatment	94.68	1	94.68	1.20	.02
Residual	5357.43	68	78.79		
Total	7443.16	70			
CPS-Establishing and maintaining shared understanding					
Treatment	45.63	1	45.63	6.52*	.09
Residual	476.25	68	7.00		
Total	680.31	70			
CPS- Establishing and maintaining team organization					
Treatment	9.05	1	9.05	.94	.01
Residual	653.91	68	9.62		
Total	846.65	70			

Note. *p<.05

Due to the corresponding lack of regression-coefficient homogeneity within groups, results for "taking appropriate action to solve the problem" violated the assumption of homogeneity

and were not suitable for ANCOVA. As a result, the alternative Johnson-Neyman procedure had to be adopted (Ji, 2016). The Johnson-Neyman statistical results are set forth in Table 10. Meanwhile, Figure 3 shows the regression lines for the experimental and the control groups obtained by the Johnson-Neyman procedure. The two regression lines appear to be non-parallel and intersect at one point, which indicates the non-equivalence between the two groups' regression coefficients and justifies the inapplicability of ANCOVA. The two lines intersect at the pre-test score of 21.83. At the upper right side of the intersection point, the control group's post-test performance is shown to be better than that of the experimental group, but the difference is not significant until the pre-test score is greater than 104.82. At the lower left corner of the intersection point, the experimental group's post-test performance appears to be better than that of the control group, but the difference is not significant until the pre-test score is lower than -53.83. According to the plot, for pre-test scores that are between -53.83 and 104.82, there are no significant differences in the two groups' post-test performances. Based on this Johnson-Neyman analysis, the actual scores for "taking appropriate action to solve the problem" ranged mainly from 6 to 24, which indicated that most students in the experimental and control groups failed to achieve any significant difference in the stated competency.

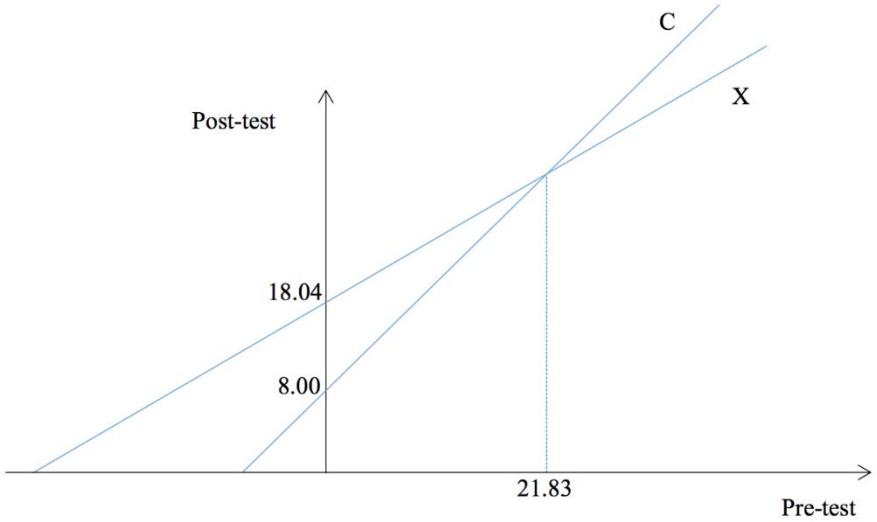
Table 10

Summary of Johnson-Neyman statistics regarding the students' abilities to take appropriate action to solve the problem

Group	$SS_{w(Xj)}$	$SS_{w(Yj)}$	CP_{wj}	*df*	$SS'_{w(Yj)}$	*df*	b_{wj}	a_{wj}
Experimental	905.91	916.43	238.47	46	853.66	45	0.26	18.04
Control	506.63	405.96	365.38	23	142.45	22	0.72	8.00

Figure 3

Johnson-Neyman plot of the experimental and control groups' performances in taking appropriate action to solve the problem.



Note 1. X represents the experimental group, and C represents the control group.

Note 2. Scores below -53.83 or over 104.82 are not shown, as the actual pre-test scores for "taking appropriate action to solve the problem" would not fall below -53.83 or exceed 104.82.

Effects of Global Partnership on Imaginative Capabilities

In terms of the overall imaginative capabilities demonstrated by the global and local teams, analytical results in Table 7 indicate that the post-test mean scores for the local and global teams were 13.75 and 8.38 higher than their respective pre-test mean scores. Apart from that, before the teaching experiment, the imagination capability of the global team students (M=121.45, SD=19.23) was stronger than that of the local team students (M=114.79, SD=17.09). After the experiment, the former (M=129.83, SD=21.19) was still greater than the latter (M=128.54, SD=21.97), although with a drastically narrowed gap between the two. As such, data analysis did not exclude the students' basic differences in imaginative capabilities. ANCOVA was adopted to determine the actual effectiveness of global partnerships in developing such capabilities.

Table 11
Analysis of participants' imaginative capability

Items	*Global partnership* (*N*=47)		*Local partnership* (*N*=24)	
	M	*SD*	*M*	*SD*
Pre-test: Imaginative Capability				
1. Initiating imagination (9)	37.26	7.37	34.79	5.98
2. Conceiving imagination (12)	50.38	8.82	47.00	7.94
3. Transforming imagination (8)	33.81	5.31	33.00	5.48
**Sum (29)*	121.45	19.23	114.79	17.09
Post-test: Imaginative Capability				
1. Initiating imagination (9)	39.87	7.03	39.79	7.36
2. Conceiving imagination (12)	53.98	9.29	52.79	9.51
3. Transforming imagination (8)	35.98	6.23	35.96	6.50
**Sum (29)*	129.83	21.19	128.54	21.97

Note. (*) represents the sum of items in each dimension.

Prior to ANCOVA, it was first necessary to determine whether the results in different ICS aspects matched the assumption of homogeneity of within-group regression coefficients. Among the four aspects of "initiating imagination" (F=4.10, p=0.05), "conceiving imagination" (F=2.12, p=0.14), "transforming imagination" (F=3.92, p=0.05), and overall imaginative capability (F=5.10, p=0.03), all aspects, except for the last one, accorded with the assumption of homogeneity. Therefore, they were suitable for ANCOVA. Meanwhile, the results pertaining to the overall imaginative capability were analysed and compared using the Johnson-Neyman procedure.

Table 12 shows the ANCOVA results for the three aspects complying with the basic assumption of within-group regression-coefficient homogeneity. Inter-group effect tests showed that none of the three aspects achieved a significant level of difference. In other words, the differences in the two groups' mean scores for initiating, conceiving, and transforming imagination were insignificant. To put it simply, the differences between the global and the local teams in terms of their imaginative performances regarding these three aspects failed to reach a statistically significant level.

Table 12
ANCOVA results for imaginative capability in different groups

Source	*SS*	*df*	*MS*	*F*	η^2
IC-Initiating imagination					
Treatment	23.749	1	23.749	.63	.01
Residual	2563.084	68	37.692		
Total	116239.000	71			
IC-Conceiving imagination					
Treatment	11.491	1	11.491	.19	.003
Residual	4200.00	68	61.77		
Total	6073.32	70			
IC-Transforming imagination					
Treatment	3.96	1	3.96	.14	.002
Residual	1931.99	68	28.41		
Total	2757.94	70			

Due to the lack of regression-coefficient homogeneity within groups, results regarding the overall imaginative capability violated the assumption of, and were not suitable for, ANCOVA. As a result, the Johnson-Neyman procedure had to be adopted instead (Ji, 2016). The statistical results obtained from the Johnson-Neyman procedure are listed in Table 13. Figure 4 shows the regression lines of the experimental and the control groups obtained by the same technique. The two regression lines appear to be non-parallel and intersect at one point, which indicates the nonequivalence between the two groups' regression coefficients and justifies the inapplicability of ANCOVA. The intersection point of the two lines is at the pre-test score of 112.13. At the upper right side of the intersection point, the control group's post-test performance is shown to be better than that of the experimental group, but the difference is not significant until the pre-test score is greater than 434.24. At the lower left corner of the intersection point, the experimental group's post-test performance appears to be better than that of the control group, but the difference is not significant until the pre-test score is lower than -245.54. According to the plot, for pre-test scores that are between -245.54 and 434.24, there are no significant differences in the two groups' post-test. Based on the Johnson-Neyman analysis, the total scores measured by the ICS ranged mainly between 29 to 174, which indicated that most students in the experimental and control groups failed to achieve any significant differences in their overall imaginative capability.

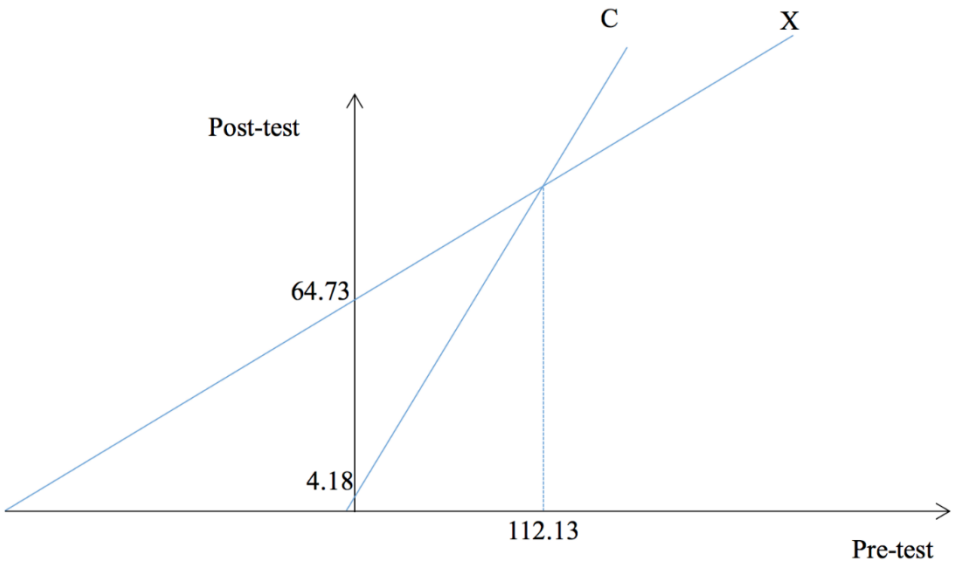
Table 13

Summary of Johnson-Neyman statistics regarding the students' overall imaginative capabilities

Group	$SS_{w(Xj)}$	$SS_{w(Yj)}$	CP_{wj}	*df*	$SS'_{w(Yj)}$	*df*	b_{wj}	a_{wj}
Experimental	17013.62	20658.64	9118.57	46	15771.47	45	0.54	64.73
Control	6719.96	11103.96	7280.71	23	3215.71	22	1.08	4.18

Figure 4

Johnson-Neyman plot of overall ICS scores of the experimental and control groups



Note 1. X represents the experimental group, and C represents the control group.

Note 2. Scores below -245.54 or over 434.24 are not shown, as the actual pre-test scores of the overall ICS would not fall below -245.54 or exceed 434.24.

According to previous research results, some important issues will be discussed in the next section for the purposes of exploring the values of the data analysis. Besides, the main limitations of this research will also be discussed for the reference of future studies.

DISCUSSION

The above data analysis regarding the students' collaborative problem-solving capabilities revealed that the local teams performed better than the global teams in establishing and maintaining shared understanding. The possible main reason behind this was that, during collaboration, the global team members were unable to react to perception, understanding, and acceptance. Instead, they could only solve problems and exchange information through limited language use. With restricted access to online information, they were also unable to continuously exchange more long-lasting and reliable information over time. Moreover, language barriers might also have obstructed their expressions and progress during idea proposal, development, and implementation. Their consequent inability to share information through effective expressions and positive interactions may have led to persistent task conflicts, followed by the failure to perform the function of establishing and maintaining shared understanding among members (West & Anderson, 1996).

Jarvenpaa and Leidner (1998) also believed that the global teams' interpersonal behaviour may have the characteristic of a heterogeneous culture, as members from different cultures are required to spend considerable time on communication and group behaviour to develop mutual values and goals and build an effective mutual trust mechanism. The teaching experiment in this research only lasted for six weeks and relied solely on computers as the main communication channel. As a result, it was harder for the global team members to perceive one another face-to-face and establish shared understanding in the same way as the local team members. It was also more difficult for them to form trustworthy teams, as they spent less time building trust and exploring each member's individual attributes. On the other hand, the local teams encountered fewer difficulties and barriers in their communication behaviour because of similarities in their languages, cultures, and geographical backgrounds. The heterogeneity of the collaborative styles in

different countries also affected the trust patterns among the global team members, making them unable to effectively exchange information and their thoughts on what they lacked. Therefore, the differences between the global and local teams in terms of their capability to establish and maintain shared understanding became an important factor affecting each team's collaborative performance and problem-solving competencies. From the perspective of imaginative capabilities, the above data analysis indicated that the performance differences between the global and local teams in terms of the overall imaginative capability and the three imagination-related aspects did not achieve statistical significance.

With reference to the suggestions by Stempfle and Badke-Schaub (2002), this research used a problem-solving procedure to guide the global team students in effective goal setting, management control, design amendment and adjustment, and model making. Nevertheless, this strategy was ineffective in stimulating the global team members' imagination, in contrast with prior research findings (Earely & Mosakowski, 2000; Hannaford, 2012; Shin et al., 2012).

The researchers speculate that there were three possible factors behind this discrepancy. First, although these previous studies suggested that global partnerships benefited imagination and its three related aspects, they depended on the prerequisite that there was no language barrier among the global team members. On the contrary, as the global teams in this research comprised members from the United States, The Bahamas, and Taiwan, the Taiwanese members were unable to properly communicate with the other members in English. Despite having integrated an appropriate strategy based on the suggestions by Stempfle and Badke-Schaub (2002), this research was unable to guarantee effective goal setting, management control, and design amendment among the global team members during their participation in the balloon-powered car activity.

The second possible factor was the close association between previous global partnership tasks and businesses. For instance, the task developed by Earely and Mosakowski (2000) was product development and sales. Although in that case the global team consisted of members from eight different countries, they were possibly motivated to engage in the task wholeheartedly because it was closely related to their own jobs and related performance pressure.

Finally, the third factor was the temporal factor, which might have resulted in the problem-solving strategy's ineffectiveness. The research by Barczak et al. (2010) proved successful in effectively managing global teams and helping them produce satisfactory imaginative contents as they developed cognitive trust, established shared statements, and integrated problems. As the collaboration period for this research spanned only six weeks, it might have been challenging for the global team members to establish cognitive trust among themselves. Therefore, despite the heterogeneity of the team, the global teamwork remained ineffective in sparking the members' imaginations.

Based on the above, the main research limitations of this research may be summarized as the language barriers and limited collaborative time within the global teams. Under such restrictions, the benefits of global partnerships to the students' collaborative problem-

solving and imaginative capabilities could hardly be found in global teamwork, even after integrating an appropriate strategy.

CONCLUSIONS AND IMPLICATIONS

According to the above data analysis results, global teams are better than local teams in "appropriate problem-solving behaviour" in balloon car-based science and technology design education activities. As Cohen and Gibson (2003) pointed out in their research, when global teams carry out project research in a virtual environment, due to the barriers of different cultural areas and Internet media, the development or imagination of collaborative problem-solving ability is limited. However, through the teaching experiment results of this research, the use of global teams is still helpful to improve the effective output value of work and the performance in the problem-solving process in the practical activities of science and technology design education. Therefore, the benefits of the use of global teams to stimulate learners' collaborative problem-solving ability is still worthy of in-depth discussion. In addition, if we explore the performance of global teams in this practical activity, we still need to strengthen the elements of "mutual understanding" and "maintain team interaction". The results of this research are consistent with those of Cohen and Gibson (2003). In the process of task execution, global teams usually have better performance in dealing with problem efficiency and process. But what is worth improving is the lack of negotiation and discussion in unstructured communication and tolerance of differences. Therefore, in the future, in seeking to develop global teams in the establishment of effective communication, empathy and other aspects should be the focus of further research.

Based on the above data analysis results, this research found that global teams performed better in the areas of "creation imagination", "conception imagination" and "transformation imagination" in the balloon car-based science and technology design education practice activities. Therefore, planning appropriate scientific and technological education activities based on the the cooperation of global teams can improve the design creative performance of team members in exploration and making in balloon car activities. It can also improve the performance of experiencing situational and learning by doing, which shows that it is more helpful to improve its performance in the imagination of practical tasks. The results of this research are consistent with previous research results. For example, Barczak et al. (2010) also believed that collaborative culture was an important antecedent for teams to improve their imagination. Therefore, global teams integrate different ideas and perspectives to solve problems and are good at using opportunities to have better learning performance, while the studies of Hannaford (2012) also pointed out that teams with different cultural backgrounds are better in imaginative learning experience in classroom teaching. As a result, teachers

should be able to design a learning environment suitable for global teams, to effectively improve students' imaginative performance.

Based on the above research results and discussion, the main conclusion was that, although this research operated a global partnership with reference to prior research, it failed to deliver the expected efficacy, as manifested in the global team members' unsatisfactory collaborative problem-solving and imaginative capabilities. The main factors driving this result were the members' inability to use a common language to achieve proper and effective information exchanges as well as their limited collaboration time, which left them unable to effectively build rapport and mutual trust. It is suggested that future studies attempt to mitigate the language barrier, prolong the collaboration period for global teams, and focus more on prioritizing the establishment of cognitive trust and emotional dependence among the team members. This should be done before adopting a suitable strategy to explore its effectiveness in developing the participants' collaborative problem-solving and imaginative capabilities. Although the global collaboration did not produce the expected collaborative problem-solving and imaginative capabilities, since other variables were not studied, other beneficial outcomes may have resulted from the collaborations; further research is therefore warranted.

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