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Development and validation of a questionnaire for assessing perspectives of World Robot Olympiad on participants

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Abstract

Many studies have examined the effects of robotics competitions, but few have investigated their effects on participants, especially from the perspectives of students, parents, and coaches. The researchers of this study developed and validated an instrument for exploring the impact of the World Robot Olympiad (WRO), a major international robotics competition, on participants from the perspectives of students, parents, and coaches. Through a literature review and expert discussion, the researchers proposed the first version of the questionnaire. After three years of data collection and three iterations as well as a reliability and validity analysis, factor analysis, and expert review, researchers developed an impact questionnaire for participants in WRO, which included 18 items in the following six dimensions: ***Learning Skill, Engineering Thinking, Emotional Engagement, Career Choice, Cooperative Solution, and Global Consciousness***. Data from 636 valid responses revealed that the questionnaire has good reliability and validity and that students, parents, and coaches all highly valued the positive impact of WRO in 2019. Data analysis indicated that, by and large, students' abilities have improved in various dimensions which were similar to those of previous research on robotics education and robotics competitions.

Keywords: Informal learning, Interdisciplinary projects, 21st century abilities, WRO

Introduction

With the development of science and technology and the increasing demand for talent training, robotics education has become popular in the world. The researchers found robotics education has great K-12 education potential in their systematic review of papers on high-level K-12 robot content knowledge teaching (Xia & Zhong, 2018). Robotics education involving group collaboration promotes college students' awareness of collaborative inquiry while encouraging their participation in science, technology, engineering, and mathematics (STEM) (Ziaeefard et al., 2017). Integration of robotics into K-12 education can enhance students' technological thinking, increase their confidence in using technology, develop their 21st-century basic skills, and enhance their self-confidence (Zviel-Girshin et al., 2020). Researchers found that when working on robotics projects, learners are exposed to concepts in various fields, which require science, technology, and problem-solving skills (Barak & Zadok, 2009). Robotics education enhances creativity, learning attitude, school life, and the ability to think logically (Abdulwahed & Hasna, 2017; Kim et al., 2017). Educational robotics can be used to teach programming, and the programming and debugging processes can train students' logical thinking and creativity. Robotics education is also beneficial in improving learners' curiosity, confidence, and achievement motivation, and cultivating their interest in computer learning (Lee et al., 2009). Teaching activities centered on robotics projects can facilitate interaction with and enhance certain aspects of programming practices (Scott et al., 2015). A study on robotics education in Russian secondary schools revealed that hundreds of new robotics courses are introduced every year in Russia, and that people receiving sophisticated robotics education in robotics centers and schools were generally able to find good jobs (Filippov et al., 2017). Researches examined 366 youths on 61 K-8 robotics teams probably from 80 countries) that participated in a FIRST LEGO League Championship conducted regression and mediation to explore the relationship between the effective team work and team performance, it is found that the team's cooperation ability is a kind of can develop skills, and with the team of experienced in a more substantial levels of participation (Menekse et al., 2017).

In the late 1990s, BotBall International Robot Contest (http://www.botball.org/) and RoboCupJunior (http://www.robocupjunior.org) were early robotics competitions, and since 2000, educational robotics competitions for school-age children have become increasingly popular worldwide (Eguchi, 2016). Some of the most popular robotics competitions include robotics competitions organized by the nonprofit FIRST (For Inspiration and Recognition of Science and Technology; http://www.usfirst.org/), such as FLL (FIRST LEGO League), FTC (FIRST Tech Challenge), FRC (FIRST Robotics Competition), and WRO (World Robot Olympiad; https://wro-association.org/). Although the idea of robotics competitions for school-age children has been around for almost two decades, the main period of development was in 2010s. WRO is an international mainstream robotics contest. In November 2003, China, Japan, South Korea, Singapore, and other countries established the international WRO Committee (now known as the WRO Advisory Council), which decided to establish a new and permanent robotics organization, and in 2019, the sixteenth edition of WRO was held. This competition hopes to provide young robot enthusiasts worldwide with a common platform. Through competitions such as the WRO, youth science and technology has become an annual world cultural exchange event. The aim of the WRO is to organize youths worldwide to participate in robotics competitions in a friendly manner and help them develop the creativity required for problem-solving. In a specific task-oriented setting schedule, participants build robots with specific functions that, in theory, have a beneficial effect in terms of academics and character-building. The WRO attracts K-12 and college students and their parents and coaches from more than 70 countries; thus, it is an appropriate platform for evaluating and measuring the impact of robotics competition on participants from different perspectives. At WRO we offer challenging competitions for everyone in the age from 6 up to 25. There are four competition categories, with their own characteristics and challenges: Regular Category, Open Category, WRO Football, Advanced Robotics Challenge (ARC, last season 2020). Each season the challenges and theme for the Regular and Open Category are developed together with the country that hosts the International Final (WRO, 2020). Miller et al. (2018) found that the number of times of participating in STEM competition (any kind) had a positive impact on students' career choice. Students who participated in only one relevant competition were 4% more likely to be interested in stem career at the end of high school than students who did not participate in any STEM competition. Students who participated in more than one competition were 12% higher than students who did not participate, and 8% higher than students who participated in only one competition.

Researches on robotics competitions in recent years mostly focused on the impact of competitions of students, with many studies looking at the impact on STEM education and so on (Eguchi, 2016). Huang et al. (2017) developed and verified a scale about WRO to assess the motivation of high school students to learn robotics and the strategies they adopted, discussed the impact on the educational application of robotics. Studies of the effects of robotic competitions on participants are relatively rare, especially from various dimensions. Our previous study used qualitative research to explore the impact of robotics competitions on participants from a broader perspective [i.e., students, parents and coaches (Chiang et al., 2020)]. With the rapid growth in the popularity of robotic competitions around the world, further analysis of participants is of great research value. In addition, robotics competitions lack large-scale international research. Therefore, the purpose of this study was to complete the development and validation of a scale to explore the impact of the World Robot Olympiad on participants from multiple dimensions.

Research purpose and questions

The main purposes of this study were, first, to develop and validate a questionnaire based on the theoretical framework to evaluate participants' perspectives after participating in WRO. Secondly, this study aimed to explore the influence of WRO participants' identity

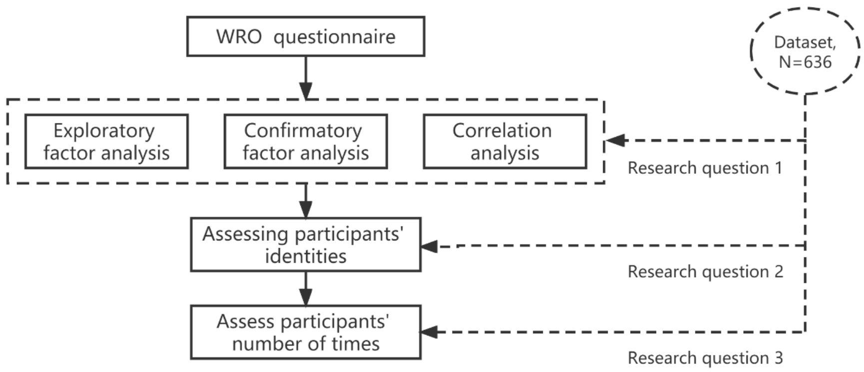

Fig. 1 Outline of the research procedure

and participation frequency on different dimensions of the questionnaire. Our research questions are the following, as shown in Figure 1.

1. Was the newly developed WRO questionnaire valid and reliable in assessing the influence of the competitions to participants?
2. How would WRO participants' identities (i.e., students, parents, coaches) exhibit mean differences on the WRO dimensions?
3. What is the effect of the number of times students participate in the WRO competition on the WRO dimensions?

Development of the questionnaire

To develop the impact questionnaire, the researchers first conducted a review of relevant literature. In 2017, our study team drafted the framework and questionnaire indicators and completed the initial pooling of items, including basic information questions, 31 five-point Likert-type questionnaire items (from "strongly agree," "agree," "undecided," "disagree," to "strongly disagree"), and three open questions. Our questionnaire took into account the age difference of students, simplified it without changing the original meaning of the sentence, and invited front-line teachers and experts in the field of educational technology to evaluate, and finally proofread and perfected by native English speakers. Some of the questions were slightly altered depending on who they were addressed to (students, parents, or coaches). In 2018, a preliminary study was conducted on local Chinese students, and questionnaires were distributed to members of the Chinese delegation returning from the 2017 WRO finals in Costa Rica. Forty-two valid questionnaires were obtained, and exploratory factor analysis was carried out using principal component analysis. The results revealed seven factors with an eigenvalue > 1, which could account for 65.15% of the total variation. Twelve items were deleted, and the remaining 19 items were analyzed using factor analysis. After seven iterations of convergence through variance maximization, the final result of factor analysis was obtained: five factors had an eigenvalue > 1, which accounted for 61.70% of the total variation. The researchers asked four STEM education and robotics experts to read and suggest revisions to ensure that the questionnaire content was in line with the actual survey and was readable. After the revisions, 19 five-point Likert-type questions were retained, formed five dimensions in the 2018 version: 21st-Century Skills, Global Awareness, Learning Ability, Emotional Participation, and Career/Major Choice. In November 2018, the researchers distributed the 2018 version of the questionnaire in Chiang Mai, Thailand. In 2019, a preliminary study was conducted on global participants in the WRO 2018 finals held in Thailand. A total of 169 valid responses (from 49 students, 68 parents, and 52 coaches) were collected. The researchers analyzed the data collected in the first two rounds and consulted experts. We learned that 21st-Century Skills were unstable in large dimensions and have many sub dimensions, of which (the original qualities of Problem-Solving and Collaboration Quality) were relatively stable， so we divided 21st-Century Skills into the original qualities of Problem-Solving and Collaboration Quality and added engineering thinking. The 2019 questionnaire thus included seven dimensions: Learning Skills, Engineering Thinking, Emotional Engagement, Career Choice, Problem-Solving, Collaboration Quality, and Global Consciousness. The development process of this round of questionnaire was shown in Table 1 below: (a) The researchers collected and analyzed the questionnaires of WRO participants in 2019 (26 items in 7 dimensions); (b) Secondly, EFA (Exploratory Factor Analysis) was performed on the original questionnaire. Considering the stability of the questionnaire structure, the researchers consulted experts after literature review, merged

Table 1 The dimensions and number of items in the questionnaire

<table>
<tr><th colspan="3">(a) 2019 WRO questionnaire</th><th colspan="2">(b) EFA</th><th colspan="2">(c) CFA</th></tr>
<tr><th>Factor</th><th>NO.</th><th>Reference</th><th>Factor</th><th>NO.</th><th>Factor</th><th>NO.</th></tr>
<tr><td>Learning Skills</td><td>5</td><td>Eguchi (2016)</td><td>Learning Skills</td><td>4</td><td>Learning Skills</td><td>3</td></tr>
<tr><td>Engineering Thinking</td><td>5</td><td>Abdulwahed and Hasna (2017); Wang (2014)</td><td>Engineering Thinking</td><td>5</td><td>Engineering Thinking</td><td>4</td></tr>
<tr><td>Emotional Engagement</td><td>2</td><td>Sklar et al. (2003)</td><td>Emotional Engagement</td><td>2</td><td>Emotional Engagement</td><td>2</td></tr>
<tr><td>Career Choice</td><td>2</td><td>Qidwai et al. (2013)</td><td>Career Choice</td><td>2</td><td>Career Choice</td><td>2</td></tr>
<tr><td>Problem-Solving</td><td>3</td><td>Eguchi (2016); Sklar et al. (2003); Peng et al. (2004)</td><td rowspan="2">Cooperative Solution</td><td rowspan="2">6</td><td rowspan="2">Cooperative Solution</td><td rowspan="2">5</td></tr>
<tr><td>Collaboration Quality</td><td>4</td><td>Nugent et al. (2009)</td></tr>
<tr><td>Global Consciousness</td><td>5</td><td>Zappe et al. (2010)</td><td>Global Consciousness</td><td>5</td><td>Global Consciousness</td><td>2</td></tr>
</table>

the two dimensions into one, and deleted two questions (24 items in 6 dimensions); (c) Then, the researcher conducted CFA (Confirmative Factor Analysis), and deleted five questions to make the model more standardized (18 items in 6 dimensions).

In analyzing the 2019 data, the researchers adjusted the seven dimensions into six after reviewing literature and consulting experts for the stability of the questionnaire. The researchers would continue to conduct large-scale global suitability and reliability and validity questionnaire studies.

Methods

Participants

This study conducted the finals of the 2019 WRO, 658 responses were obtained online and offline. The data of 22 individuals (3.34%) were excluded from the analyses because (a) they did not complete the questionnaire or (b) they filled in the questionnaires casually in order to get a gift (researchers handed out questionnaires at the competition). Three different categories of questionnaires were created for students, parents, and coaches. Parents and coaches have witnessed the growth and changes of students in the process of participating in the competition. Their views on the impact of robotic competitions on participants are valuable for research. Finally, there were a total of 636 (online: 263; offline: 373) valid participants whose competition information was shown in Table 2.

Student questionnaires: A total of 264 students (males, 68.56%) participated in our research, they won the national competition through selection and finally represented their country in the WRO competition. Of them, all of the students were under the age of 25 (< 12 = 24.24%; 13-15 = 35.23%; 16-19 = 35.61%; 20-25 = 4.92%). The number of people participating in the Open Category competition (n = 126, 47.73%) was the highest. Among the age groups, 33.33% were in the junior high school group, 36.74% were in the senior

Table 2 Background information of participants

Variables	Classification	Number	Percent
Identity	Student	264	41.51%
	Parent	126	19.81%
	Coach	246	38.68%
Gender	Male	405	63.68%
	Female	219	34.43%
	N/A	12	1.89%
Frequency	1	207	32.55%
	2	150	23.58%
	3	116	18.24%
	4	50	7.86%
	5	24	3.77%
	>=6	89	14.00%

high school group, and the rest were in the younger grade group (wedo = 3.41%; elementary = 20.45%). Furthermore, many (39.77%) of the students participated in the competition for the first time.

Parent questionnaires: 126 parents answered the questionnaire, of whom 46.03% had a master's degree or higher and only 4.76% had a highest education level of junior high school or below. It can be speculated that the higher the level of parents' education, the more concerned they are about the students' competition.

Coach questionnaires: The coach is responsible for recruiting and training students, and leading the team to participate in WRO. We surveyed 246 coaches, including 180 men (73.17%) and 64 women (26.02%). In the type of competitions, 65.04% chose the Regular Category, and the number of coaches who choose Advanced Robotics Challenge (ARC) (1.63%) was by far the lowest. Among the coaches, 65 (26.42%) were high school teachers, and only 14 (5.69%) were university teachers.

Instrument

Through engagement in robotics education and participation in international robotics competitions, we compiled six factors affecting overall development: Learning Skills ($\alpha = .86$), Engineering Thinking ($\alpha = .89$), Emotional Engagement ($\alpha = .77$), Career Choice ($\alpha = .79$), Cooperative Solution ($\alpha = .91$), and Global Consciousness ($\alpha = .77$). A detailed description is provided as follows:

a. Learning Skills: Learning Skills includes self-learning ability, computational learning, and programming. Learning of basic disciplines can be observed constantly in participants regardless of geographical and cultural differences (Eguchi, 2016).

b. Engineering Thinking: Engineering Thinking refers to an approach of considering all issues, including engineering decision-making, engineering design, and engineering operation, when solving a problem. "Engineering design" is the process of making decisions and operating methods. Engineering design thinking involves the participation of interpersonal communication, cognition, and management skills or abilities, such as teamwork, communication, decision-making, and problem-solving (Abdulwahed & Hasna, 2017).

c. Emotional Engagement: Emotional Engagement in this context includes confidence, self-efficacy, and an interest in robotics. Self-efficacy refers to an individual's perception of his or her ability to perform a task (Lin et al., 2019). People have an enduring interest in activities that they deem themselves competent in and hold positive expectations about the outcomes of these activities. A survey reported that robotics competitions increased students' confidence in using technology and their interest in science and math (Sklar et al., 2003).

d. Career Choice: Participants in robotics competitions increase their interest in computer science, physics, and engineering, which are likely to influence their choice of future careers (Qidwai et al., 2013). Therefore, the researchers believe that career choice has special investigation value.

e. Cooperative Solution: WRO success relies heavily on teamwork. Participants are supposed to work together on a challenging task, thus enhancing their teamwork and leadership abilities together while resolving conflicts and sharing the joy of success.

f. Global Consciousness: Global Consciousness involves understanding different cultures, social and cross-cultural connections, and developing a sense of responsibility and national pride. Studying or working abroad is considered to be an efficient means of improving global awareness (Zappe et al., 2010). Therefore, participating in the WRO can help participants broaden their perspective.

Data analysis

To answer the research questions posed in this study, the researcher performed the following data analysis steps according to the questionnaire development and validation process of Willner et al. (2020). First, we conducted reliability and exploratory factor analysis on 263 online participants, and then performed confirmatory factor analysis on 636 participants (the sum of online and offline). Finally, the researchers explored the perspectives of identity (students, parents, coaches) and the number of times on the six dimensions.

Results

Exploratory factor analysis

There are three types of validity: content, calibration, and structural validity. We mainly used content validity and structural validity. Content validity refers to expert judgment and questionnaires before and after testing. The questionnaire was developed after a review of the literature, and experts related to STEM education and robotics reviewed and improved the questionnaire. Structural validity refers to the correspondence between measurement items and measurement dimensions. Two methods are available to verify the validity of the questionnaire: exploratory factor analysis and confirmatory factor analysis. We first performed exploratory factor analysis on the data.

The factorability was supported by Bartlett's test of sphericity, $\chi^2(325, N=263) = 4676.13$, $p < .001$, and the Kaiser-Meyer-Olkin measure of sampling adequacy of .94, Table 3 presents the reserved items and corresponding dimensions. Since the 2019 WRO questionnaire had seven dimensions, researchers set the common factor as 7 when conducting factor analysis. Following Pett et al. (2003) suggestions, the factors were refined by using item reduction based on the following criteria: (a) factor loading of the item was less than 0.4, and (b) the item appeared in the other factor. The results yielded suggested the elimination of two items. In addition, after conducting EFA on the initial questionnaire (WRO2019), the researchers found that the Problem-Solving dimension and the Collaboration Quality dimension were clustered within the same factor. The researchers finally combined the two dimensions into the Cooperative Solution dimension by consulting experts and reviewing literature (Abdu & Schwarz, 2020). The final run of EFA on the six-factor oblique solution with 24 items accounted for 75.67% of total variance (Table 3).

Table 3 Rotated factor loadings and Cronbach's α values for the six dimensions (subquestionnaires) of the WRO's influence on students

Item	Learning Skills	Engineering Thinking	Emotional Engagement	Career Choice	Cooperative Solution	Global Consciousness
Learning Skills α = .86						
1	.78					
2	.63					
3	.74					
4	.42					
Engineering Thinking α = .89						
6		.79				
7		.71				
8		.75				
9		.51				
10		.48				
Emotional Engagement α = .77						
11			.59			
12			.53			
Career Choice α = .79						
13				.81		
14				.74		
Cooperative Solution α = .91						
16					.52	
17					.53	
18					.69	
19					.71	
20					.76	
21					.81	
Global Consciousness α = .77						
22						.64
23						.81
24						.79
25						.90
26						.88
Eigenvalue	1.15	1.85	0.78	1.00	11.77	1.71
% of variance	11.54	15.09	5.49	9.53	16.80	17.22

[a]Overall α = .95, the total variance explained is 75.67%.

The variance of the six factors were 11.54%, 15.09%, 5.49%, 9.53%, 16.80%, and 17.22% respectively (Table 3), and the cumulative variance interpretation rate after rotation was 75.67% (which is > 50%). This indicates that the information of the research items can be effectively extracted. The overall internal reliability index (α) of the questionnaire was .95, indicating the model is ideal. However, for the third dimension, the eigenvalue (0.78) is relatively low, and students' emotional engagement cannot explain the problem well. This may be because of too few questions (two questions) in this dimension and because students' emotions are more unstable; subsequent research can modify the questions and increase the number.

Confirmatory factor analysis

The proposed model was tested using AMOS statistical software, and tests of construct validity, convergent validity, and discriminant efficiency were applied. We used confirmatory factor analysis to verify the hypothesized six-factor model, removing items with low factor loading coefficients (< .7) (Fornell & Larcker, 1981). It should be noted that although the factor loadings of questions 8 and 9 are less than .7 (infinitely close to .7), the researchers believed that they were within the acceptable range and retained them. Therefore, the questionnaire changed from 24 questions to 18 questions (Table 4). In addition, the model's absolute fitness index (RMSEA) was .05 (< .1), and the value-added

Table 4 Construct validity and convergent validity of measurement model

Factor load coefficient table					
Factor	Item	p	Std. Estimate	AVE	CR
Learning Skills	Q1	-	.73		
	Q2	0	.74	.53	.77
	Q3	0	.71		
Engineering Thinking	Q6	-	.74		
	Q7	0	.75	.52	.81
	Q8	0	.70		
	Q9	0	.68		
Emotional Engagement	Q11	-	.71	.51	.67
	Q12	0	.71		
Career Choice	Q13	-	.73	.58	.74
	Q14	0	.80		
Cooperative Solution	Q17	-	.74		
	Q18	0	.73		
	Q19	0	.73	.52	.84
	Q20	0	.70		
	Q21	0	.71		
Global Consciousness	Q25	-	.89	.69	.81
	Q26	0	.76		

fitness indices of NFI, IFI, GFI, and CFI were .94, .96, .95, and .96, respectively (all > .9), and all the results accorded with the validity index of the whole model structure.

Average variance extracted (AVE) and composite reliability (CR) were used to analyze the convergent validity of the model. Generally, an AVE of > .5 and CR of > .7 indicates high polymerization validity. A confirmatory factor analysis was conducted on 6 factors and 18 analysis items. The AVE values corresponding to a total of six factors were > .5, the CR value in the third dimension was close to .7 (.67), and those in the remaining dimensions were > .7 (Table 4). Thus, the model had higher convergent validity in all dimensions.

We tested the multidimensional structure of the questionnaire using confirmatory factor analysis with the maximum likelihood estimation method (Jöreskog & Sörbom, 2004) to evaluate the instrument's discriminant validity. If a factor's AVE square root value of all dimensions was greater than the correlation coefficient between this factor and other factors, it indicated that the questionnaire had good discriminant validity (Fornell & Larcker, 1981). In Table 5, the diagonal square root exceeded any nondiagonal ones, showing that our model had high reliability.

Correlation analysis

Correlation analysis is used to study the relationship between quantitative data. The value lies between -1 and 1, and the larger the absolute value, the closer the relationship. As detailed in the previous section, the structure of the topic was determined by tests of reliability and validity. Table 6 presents the cross-correlation matrix among the six dimensions. All the correlations reached the significance level of .01, indicating significant differences among all dimensions and, thus, an excellent questionnaire structure.

Table 5 Discriminant validity of the questionnaire

Discriminant validity: Pearson correlation and AVE square root value						
	Learning Skills	Engineering Thinking	Emotional Engagement	Career Choice	Cooperative Solution	Global Consciousness
Learning Skills	.73					
Engineering Thinking	.65	.72				
Emotional Engagement	.54	.66	.71			
Career Choice	.48	.55	.49	.76		
Cooperative Solution	.63	.70	.66	.54	.72	
Global Consciousness	.32	.38	.28	.31	.36	.83

Note: Diagonal numbers are AVE square root values

Table 6 Correlation matrix of the influence of the WRO on students in six dimensions

	Learning Skills	Engineering Thinking	Emotional Engagement	Career Choice	Cooperative Solution	Global Consciousness
Learning Skills	1					
Engineering Thinking	.63**	1				
Emotional Engagement	.54**	.64**	1			
Career Choice	.49**	.53**	.49**	1		
Cooperative Solution	.61**	.70**	.66**	.51**	1	
Global Consciousness	.36**	.41**	.34**	.34**	.40**	1

** $p < 0.01$

Identity differences in the questionnaire

A one-way analysis of variance comparing the responses of students, parents, and coaches in the dimensions of Learning Skills, Engineering Thinking, Emotional Engagement, Career Choice, Cooperative Solution, and Global Consciousness revealed significant differences between the three identities in all six dimensions (all $p < .05$, Table 7). Figure 2 showed the scores of the three identities in six dimensions, the average scores of the students were markedly different (lower) than those of parents and coaches in all dimensions.

Number of times participants took part in the WRO

The questionnaire examined the number of times the students has participated in the competition (six options: 1–5 times and ≥ 6 times). The results revealed that 32.55%,

Table 7 Identity of the competition attendees who completed the questionnaire

	Identity (Mean ± SD)			F	*p*
Type	Student	Parent	Coach		
Learning Skills	3.97±0.87	4.22±0.80	4.31±0.75	11.23	< .001
Engineering Thinking	4.03±0.81	4.32±0.67	4.30±0.65	11.52	< .001
Emotional Engagement	4.01±0.90	4.44±0.69	4.34±0.69	17.46	< .001
Career Choice	4.04±1.00	4.36±0.81	4.31±0.78	8.38	< .001
Cooperative Solution	4.04±0.77	4.31±0.69	4.28±0.68	9.55	< .001
Global Consciousness	3.85±1.16	4.21±0.85	4.10±0.96	6.42	0.002

1 point: *strongly disagree*, 2 points: *disagree*, 3 points: *neutral*, 4 points: *agree*, 5 points: *strongly agree*

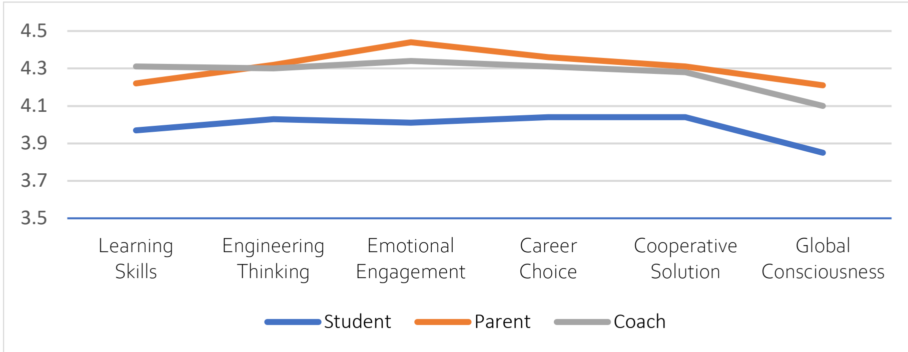

Fig. 2 Changes in scores in six dimensions of participation in competitions

23.58%, 18.24%, 7.86%, 3.77%, and 14.00% of students were participating for the first, second, third, fourth, fifth, and sixth (or more) time, respectively. Table 8 presents the mean ± standard deviation of the scores in the six dimensions stratified by number of times students participated in the WRO. The data indicate that the number of times students participated in the competition resulted in significant differences in the dimensions of Learning Skills, Emotional Engagement, Career Choice, and Global Consciousness. In addition, as shown in Figure 3, students who took part in the competition ≥ 6 times scored higher than others in six dimensions.

Discussion and implications

In this study, an impact questionnaire for WRO participants was developed and revised based on 3 consecutive years of data collection and analysis. The questionnaire has high reliability and effectiveness, which can help educators and educational researchers better

Table 8 Scores for the dimensions stratified by the number of times a student has participated in the competition

	Number of times (Mean ± SD)						
	1	2	3	4	5	6	p
Learning Skills	4.08±0.85	4.14±0.83	4.11±0.80	4.14±0.95	3.97±0.96	4.46±0.59	.009
Engineering Thinking	4.12±0.78	4.21±0.75	4.20±0.61	4.14±0.85	4.00±0.91	4.38±0.63	.077
Emotional Engagement	4.16±0.83	4.23±0.80	4.16±0.84	4.12±0.89	4.31±0.85	4.46±0.57	.051
Career Choice	4.07±0.98	4.28±0.84	4.17±0.87	4.36±0.80	4.0±1.08	4.43±0.71	.008
Cooperative Solution	4.10±0.79	4.25±0.69	4.21±0.62	4.09±0.85	4.18±0.87	4.32±0.67	.178
Global Consciousness	4.00±1.04	4.13±0.97	4.00±1.03	3.74±1.12	3.31±1.41	4.30±0.89	< .001

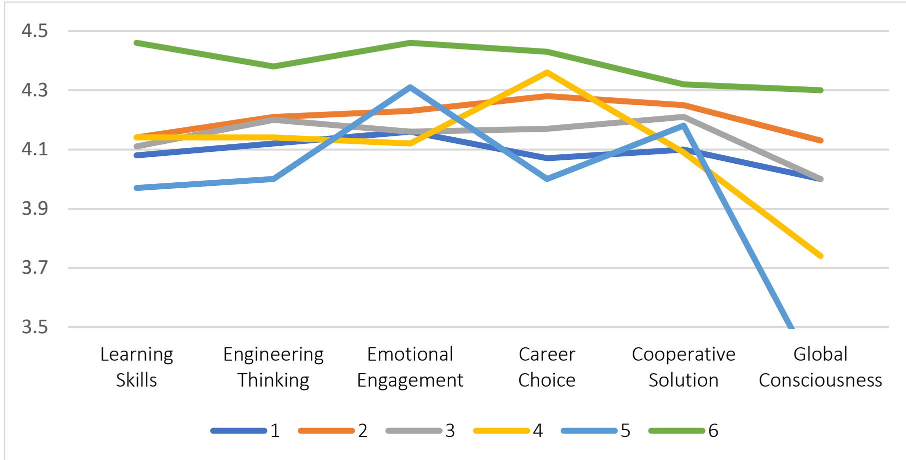

Fig. 3 Changes in scores in six dimensions of participation in competitions

understand the influence of robotics competitions on participants. In this study, six dimensions were constructed through exploratory and confirmatory factor analyses: Learning Skill, Engineering Thinking, Emotional Engagement, Career Choice, Cooperative Solution, and Global Consciousness. Learning Skills measures the knowledge and ability of students, Engineering Thinking assesses students' thinking patterns and activities, Emotional Participation measures the impact of students' participation in the competition on their internal emotions, Career Choice assesses students' interests and employment directions, Collaborative Resolution evaluates students' teamwork and problem-solving skills, and Global Consciousness assesses their intercultural communication ability, responsibility, and national honor.

The study showed that for identity differences in robotics competitions, students scored significantly lower in six dimensions than in parent or coach dimensions. This may be because parents and coaches valued the influence of the competition on students' knowledge and ability, while students tended to communicate with foreigners and make more friends (Chiang et al., 2020). As for the number of times of participating in the WRO, the study found that students who participated in six or more times scored higher in all dimensions than students who participated in other times. At present, there are relatively few studies on the impact of students' experience on robotics competitions, which is worthy of follow-up research and discussion.

In general, the findings of this study were similar to those of previous research on robotics education and robotics competitions. Educational robots have received increasing attention over the past few decades. Robotics education and robotics competitions are being widely adopted worldwide as tools to attract students to learn and improve their technical and social skills. In many situations, girls are less interested in programming education and thus need more training time to reach the same skill levels as boys (Atmatzidou &

Demetriadis, 2016). However, this study demonstrated that girls' average score in all dimensions was slightly higher than boys.

The researchers of the present study conducted a literature search and used a combination of questionnaires and interviews across three years to increase the sample size and strengthen the comprehensiveness and scientificity of the data; however, some unavoidable limitations remain. First, the number of questions in the dimensions of Emotional Engagement and Career Choice was too small to evaluate the impact of students' participation in the competition on their emotions and employment direction. The number of questions should be increased in future studies. Second, students' family background and type of school may considerably influence their motivation and emotions; more variables must be examined in subsequent studies. Finally, gender studies can be added to future research.

In conclusion, the survey results highlighted that WRO has various positive effects on participants. As the influence of WRO continues to increase, more students from all over the world are willing to participate, which can better promote cultural integration and overall personal development.

Abbreviations

ARC: Advanced Robotics Challenge; AVE: Average variance extracted; CFA: Confirmative Factor Analysis; CR: Composite reliability; EFA: Exploratory Factor Analysis; FIRST: For Inspiration and Recognition of Science and Technology; FLL: FIRST LEGO League; FRC: FIRST Robotics Competition; FTC: FIRST Tech Challenge; STEM: Science, technology, engineering, and mathematics; WRO: World Robot Olympiad.

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Authors' contributions

Feng-Kuang Chiang directed the project, guided and revised the manuscript.

Yicong Zhang and Yanan Lu conducted statistical analysis on data and wrote the manuscript.

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Declarations

Competing interests

This research was carried out according to ethical guidelines. No conflict of interest exits in the submission of this manuscript, and the manuscript is approved. All research participants are given pertinent information to make an informed consent to participate.

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