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Psychometric Validation of the Robotics Interest Questionnaire (RIQ) Scale with Italian Teachers

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Abstract

In recent years, numerous research studies have highlighted how teachers' perceptions of educational robotics (ER) and their sense of self-efficacy can influence the learning process. Although different instruments exist to investigate teachers' perspectives on ER, the Robotics Interest Questionnaire (RIQ) scale, developed within the Portuguese K–12 education framework to analyse the impact of domain knowledge (i.e. coding and robotics), interest in robotics, and confidence in one's self-efficacy as a robotics teacher, was used in the present work. This instrument has been validated in Portugal, meeting rigorous statistical and reliability measures that our work intends to verify in its Italian version. To test the validity of the instrument, the Teacher Self-Efficacy (QAI) Questionnaire, already validated in Italian and accredited in the literature, was administered jointly. The instruments were administered to a non-probabilistic sample of 823 teachers working in different school orders. Exploratory and confirmatory factor analyses were carried out, confirming a four-factor model. The results suggest the applicability of the RIQ instrument in the Italian school context to test teachers' levels of interest, knowledge, problem-solving, collaborative work, and sense of self-efficacy, successfully discriminating between experienced and inexperienced ER teachers. These constructs, as suggested in multiple works, are relevant factors in promoting the use of robotics for educational purposes.

Keywords Educational robotics · Psychometric validation · Teacher's attitudes · Teacher's self-confidence · EFA · CFA

Introduction

In the past decade, artificial intelligence and robotics have been the focus of attention both in the educational and didactic context and in the academic and research context. This growing interest on the part of the scientific and pedagogical education community is connected to the phenomenon of technological affirmation in contemporary international society, which, by affecting the everyday life of each individual, is giving rise to a new era: the digital era. This process has also involved educational institutions, which have been confronted with new challenges, such as the use of AI. There is therefore a need to search for solutions and new perspectives on how to use digital technologies in education and, in particular, on the use of educational robotics (ER), both to meet the needs of schools, stimulating learning *with* and *to* technology with the ultimate aim of fostering digital literacy, and to ensure the development of these skills in the continuous training of teaching staff. Educational policies and international documents (Redecker, 2017; ISTE, 2017; NAEYC & Fred Rogers Centre, 2012) have outlined a new profile of teaching competence, in which digital skills play a privileged role in the training of the twenty-first-century education professional. Of particular importance are the Computational Thinking Competencies for Educators (Trust, 2018), which aim to support all educators in contributing to the development of computational problem-solving in students.

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There is, however, still a need to define which aspects of teachers' professionalism are most involved and from which they derive the greatest 'benefits' for ER learning outcomes. To do this, it is important to identify a (validated) instrument to measure the appropriate disposition of teachers and their adequate preparation. The result of such measurements could also allow comparison and improvement of the different training paths of trainee and in-service teachers in Italy. There are many tools for investigating teachers' perspectives, perceptions, and attitudes towards ER (Alsoliman, 2018; Bonaiuti et al., 2022a, b; Castro et al., 2018; Chevalier et al., 2016; Di Battista et al., 2020; Khanlari, 2016, 2019; Negrini, 2020; Oreški, 2021; Papadakis & Kalogiannakis, 2022; Reich-Stiebert & Eyssel, 2015, 2016; Román-Graván et al., 2020; Sullivan & Moriarty, 2009; Tang et al., 2023), but none of these has been validated. Among the few validated ones (Dorotea et al., 2021; Jaipal-Jamani & Angeli, 2017; Piedade, 2020; Tzagaraki et al., 2022), we considered that the Robotics Interest Questionnaire (RIQ; Dorotea et al., 2021), which investigates teachers' interest in ER by assessing its psychometric characteristics and factorial structure, represented the most comprehensive and reliable tool, as it also takes into account the contributions of others.

The aim of our work was to validate an Italian version of the RIQ scale and investigate its psychometric properties, as well as evaluate its usefulness in teaching in the Italian context. The RIQ identifies four dimensions through exploratory (EFA) and confirmatory factor analysis (CFA): knowledge, interest, sense of self-efficacy, and problem-solving and teamwork. These are relevant factors in promoting teachers' use of ER for teaching purposes (Dorotea et al., 2021; Piedade, 2021). Investigation of these dimensions could have implications for the educational system and affect multiple aspects, including choices regarding teacher training courses or teaching practices best suited to different educational contexts (Schina et al., 2021; Smith & Tyler, 2011). The results of the questionnaire provide indicators for institutional training agencies on university and in-service teacher training processes and on teachers' knowledge of and interest in science, technology, engineering, and math (STEM) and ER. It might also provide an indication of teachers' self-efficacy, which is very influential in the first years of teaching (Tschannen-Moran & Hoy, 2007), and on teachers' team-working skills, which are essential to ensure inclusive education (Holmqvist & Lelinge, 2021; Finkelstein et al., 2019). The feedback from this questionnaire could be useful in structuring an innovative and interdisciplinary teacher training programme for newly recruited teachers, while also encouraging older teachers to self-assess their knowledge of and interest in ER, thus triggering and supporting virtuous processes of transformative and metacognitive learning. Appropriate training would facilitate the establishment of best practices for the implementation of robotics activities.

Theoretical Framework Underlying the Four RIQ Factors

The instrument identifies four dimensions related to the quality of ER teaching at school (see Fig. 1). These dimensions are consistent with the copious literature, which adequately warrants them; we provide a summary in the following subsections.

Self-efficacy, identified as the teachers' confidence in their own abilities, is closely related to their success in teaching ER. The interest of teachers in ER and STEM is an additional factor capable of guiding success in teaching ER at school. The ability to work in teams and the problem-solving skills of the teacher are factors that the RIQ, as well as the scientific literature, indicate as being important (although not as crucial as the previous factors) for designing appropriate instructional activities at school.

Self-Efficacy and Teaching

Self-efficacy, while a difficult construct to assess adequately (Tschannen-Moran & Hoy, 2001), has also started to receive international attention from an educational perspective. Bandura (1994) defined it as the strength of a subject's belief and confidence in his or her ability to organise and complete a task through self-measurement of the degree to which he or she evaluates task performance. This system influences personal perceptions of situations and consequently the behaviours enacted by the individual in response to various contextual inputs. Bandura (1977)

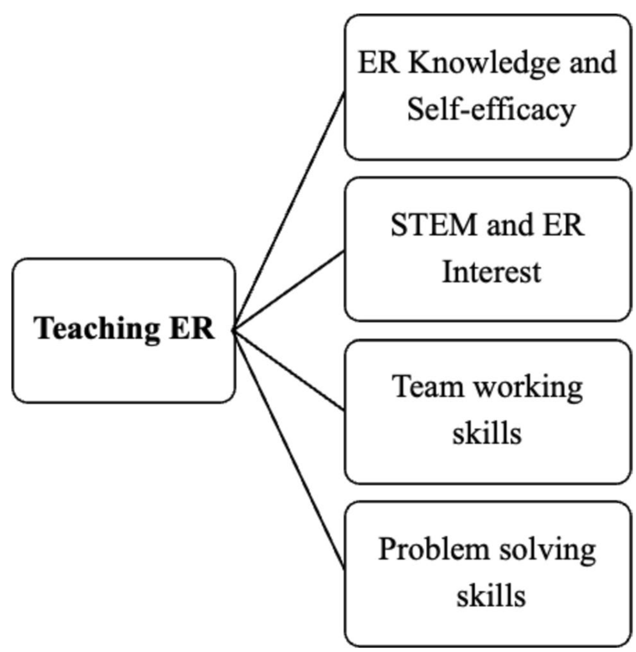

Fig. 1 Factors leading to interest in the teaching of educational robotics

distinguished between outcome expectancy, or the estimation that an action will lead to a certain outcome, and efficacy expectancy, or the very belief that one is capable of performing an action to achieve a predetermined goal. In line with Bandura's social cognitive theory, Tschannen-Moran et al. (1998) proposed an integrated model in which teachers' perceptions and competence positively influence competence itself, which can affect students' academic success, from the quality of teaching to the instructional strategies implemented.

A high level of teacher self-efficacy has also been associated with positive perceptions of collaboration, openness to innovation, and readiness for continuing education (Collie et al., 2012; Mannila et al., 2018; Ninković & Knežević Florić, 2018; Pas et al., 2012). Teachers' self-efficacy is critical for the development of digital and computational skills to provide students with current and up-to-date instruction (Mannila et al., 2018). There is a need to support teachers in developing self-efficacy in digital skills: studies have shown that good levels of self-efficacy in the discipline of teaching support lifelong learning improve the learning environment and discourage states/syndromes of burnout. Bandura (1994) noted that the degree of self-efficacy changes throughout life, and it can be influenced in multiple ways, such as by experiences of competence, observation of competent social role models, social persuasion that one can be competent, and verbal feedback. Considering that most teachers called to in-service training have not had enough practice in teaching ER, observation of models and social feedback seem to be factors that can improve the self-efficacy beliefs not only of in-service teachers but also of teachers still in training.

According to some scientific evidence (Tschannen-Moran & Hoy, 2007), contextual factors (e.g. peer support and teaching resources) promote the construction of teachers' self-efficacy and are particularly influential in the early years of service. For this reason, instruments measuring teacher self-efficacy are relevant if administered as early as pre-service and university training, collaterally to internship and/or laboratory activities. In recent years, numerous research studies have shown how teachers' perceptions and their sense of self-efficacy can in fact influence learning processes. Improving one's ability to implement teaching, learn new strategies, and better present teaching content has, therefore, a significant impact on motivation, school inclusion, and, consequently, on learning itself (Giannandrea et al., 2021). Jaipal-Jamani and Angeli (2017), in line with the above, asserted that engaging with robotics as part of a training course can improve teachers' perceptions of self-efficacy and encourage the implementation of ER activities to teach science disciplines and computational thinking (CT) skills.

STEM and ER

Summaries of the literature published in the last decade on ER (e.g. Benitti, 2012; Bonaiuti et al., 2022a, b; Kyriazopoulos et al., 2021) have demonstrated the increase in research data, making explicit the educational purposes, areas of application, and scientific evidence in terms of the educational effectiveness of the practice itself. Robots in the educational context have emerged as a viable tool since the time of Papert, who called it an 'object with which to reason' (Harel & Papert, 1991), borrowing Winnicott's (1971) concept of the transitional object. The robotics artefact still proves valuable today as a mental tool (Mikropoulos & Bellou, 2013) for the acquisition of twenty-first-century (Alimisis, 2013) and STEM skills (Benitti, 2012; Ching et al., 2019; Nugent et al., 2009; Sullivan, 2008; Toh et al., 2016), as robots can boost motivation and improve student learning and achievement (Anwar et al., 2019; Athanasiou et al., 2019; Lancheros-Cuesta & Fabregat, 2022; Scaradozzi et al., 2015; Vlasopoulou et al., 2021).

The use of robots in education has also supported the inclusion of students with special educational needs and the protection of gender equality (Daniela & Lytras, 2019; Sullivan & Bers, 2019; Syriopoulou-Delli & Gkiolnta, 2021). Indeed, several researchers have argued that interacting with robots also develops social skills (Mitnik et al., 2008; Owens et al., 2008; Toh et al., 2016), teamwork skills (Johnson, 2003) and cooperative learning skills (Nourbakhsh et al., 2005). It follows that fostering ER in schools and training teachers to design and implement such activities, as the directions and school curricula of several nations require, is a priority for the new millennium. ER activities, compared to traditional teaching, actively involve pupils, making teaching more engaging (Eguchi, 2014). In their review 'teacher training on educational robotics', Giannandrea et al. (2021) stated that pre-service and in-service training allowed teachers not only to readjust and integrate knowledge about robotics and teaching methodologies (essential for acquiring specific skills) but also to actually understand the benefits of technological apparatuses in the pedagogical context. In fact, it turns out that there are numerous studies that have demonstrated the importance of interest and knowledge about content to teach it well (Hattie, 2012; Shulman, 1987). Teachers' attitudes, perceptions, and beliefs about ER are based on such understandings, which can shape as stimuli or act as a limitation to the implementation of the practice itself (Hew & Brush, 2007; Lawson & Comber, 1999). A study by Papadakis and Kalogiannakis (2021) has shown that a teacher's positive attitude about robotics practice is positively associated with ER knowledge.

Teamwork and Self-Efficacy

There are numerous works in the literature that emphasise the importance of collaboration between teachers. In a systematic review of the relationship between teacher collaboration and student academic success, García-Martínez et al. (2021) revealed that the most widely used collaborative modalities were related to instructional processes and improving student academic performance. They pointed out that although building a collaborative climate is demanding and challenging, collaborative support between teachers is crucial to school success. Vangrieken et al. (2015), in an earlier systematic review, showed that the observed benefits of teacher collaboration in the literature can be found at three different levels: student, teacher, and school. The main advantages reported at the teacher level include teachers experiencing the following: being more motivated, a decreased workload, a positive impact on teacher morale, greater efficiency, increased communication, improved technological skills, shared instruction strategies, and teaching suggestions and reduced personal isolation. At the student level, it was reported to improve understanding and performance. At the organisational level, communication, openness, and participation are key for creating a climate of trust so that the benefits reported include a positive influence on the perception that the school climate is supportive of innovation, better adaptation, and more innovation, a cultural shift to more equity, a school-wide attention to the needs of students, a flattened power structure, and the fostering of a professional culture of intellectual enquiry. In other words, teacher teamwork is a force that positively influences the whole school community (Mora-Ruano et al., 2019). The TALIS 2013 survey found that collaboration between teachers is among the factors that can boost teacher job satisfaction (OECD, 2014), which is a core element of an effective teacher (Mora-Ruano et al., 2019).

Professional relationships based on trust contribute to the development of a common vision for the school (García-Martínez et al., 2021). Teachers who work collaboratively also increase their effectiveness and expertise (Hattie, 2015), helping to improve self-efficacy (Puchner & Taylor, 2006). Bandura himself (1977) recognised the fact that individuals do not work as social isolates and that people form beliefs about the collective capabilities of the groups to which they belong. He defined collective efficacy as ‘a group’s shared belief in its conjoint capabilities to organise and execute the courses of action required to produce given levels of attainments’ (p. 477). As Klassen et al. (2011) stated, teachers’ collective efficacy refers to the beliefs that teachers possess in their collective the capabilities to help students develop and learn. It is reasonable to assume that beliefs about the ability and effectiveness of the teacher group in a school to cope with a variety of challenges also support and nurture beliefs about personal effectiveness. It is no coincidence that Klassen et al. (2011), in a study that explored the relationship between teachers’ collective efficacy, job stress, and job satisfaction, stated that when teachers experience challenges and setbacks that may lower their individual motivation, these setbacks may be mitigated by beliefs about their colleagues’ collective ability to affect change. Given the close link between teamwork and self-efficacy and between the latter and student learning outcomes, one dimension analysed by the questionnaire is precisely related to collaboration between teachers. The positive effects of teamwork by teachers engaged in STEM teaching are also strongly confirmed by a specific synthesis of the literature.

Problem-Solving and Computational Thinking

Problem-solving is a decisive factor for success in teaching. Problem-solving promotes meaningful learning, knowledge transfer, metacognitive skills, engagement, critical thinking, and collaboration among students. It helps students connect existing knowledge to real-world situations, develop problem-solving abilities, and enhance their overall learning experience when supported by effective teaching strategies. Through meta-analyses of the literature, Hattie (2012) found that the ability to solve problem in teaching has a high effect size ($d=0.61$) and is capable of significantly improving students’ learning. Problem-solving leads students to reason about the process leading to the solution, the validity of the solution, and the possible alternatives, as well as enabling them to reflect metacognitively on their own strategies. Problem-solving, by challenging students to solve real problems or authentic learning situations, makes learning motivating and, because it often requires group work, promotes peer learning and constructive discussion.

Papert (1980), among the first to identify the potential of robotics to develop children’s thinking skills, identified the promotion of problem-solving as one of the strengths of this type of experience. From this perspective, having a robot (virtual or real) explore the world around it requires the ability to plan a series of actions by predicting their consequences in view of a given goal to be achieved and allows students to formulate and then to select, from among the many ideas and models available to them, the most functional ones. Giving students the opportunity to programme the behaviour of virtual agents in an unknown context is also a way to develop CT. This concept was taken up by Wing (2006) and later by others (Brennan & Resnick, 2012; Chalmers & Nason, 2017; Kazakoff Myers & Bers, 2014) in terms of its implications for students’ ability to engage in abstraction, decomposition, verification, debugging, and modelling during learning processes involving building, programming, and interacting with robots. In addition to the National Research Council (2010)—and after Wing—many other authors (Brennan & Resnick, 2012; Catlin & Woollard, 2014; Piedade et al., 2020) have taken an interest in this topic.

CT has emerged as a multifaceted construct, defined as a set of skills that enable us to think like a computer scientist when faced with a problem: thus, it involves posing, finding, and solving problems; abstraction and logical thinking; pattern recognition; and the ability to effectively manage information across technologies. As reported by Selby and Woollard (2013), Hoppe and Werneburg (2019), and the International Society for Technology in Education (ISTE) and the Computer Science Teacher Association (CSTA), the operational definition of CT in K–12 is a problem-solving process that includes (but is not limited to) the ability to think in abstractions, in terms of decomposition and algorithmically, and in terms of evaluations and generalisations. These skills are supported by attitudes that take the form of essential dimensions of CT: for example, confidence in dealing with complexity, persistence in working with difficult problems, the ability to deal with open-ended problems, and the ability to communicate and work with others to achieve a common goal or solution. CT therefore represents a type of analytical thinking that has many similarities with mathematics (problem-solving), engineering (design), and science (systematic analysis) but at the same time is useful in supporting and organising reasoning in numerous other disciplines, to the point of suggesting its introduction in the early childhood curriculum (Bers, 2021). However, CT does not turn out to be a discipline per se in K–12 education, but rather an aptitude—that is, a universally applicable set of skills that are essential for everyone in the twenty-first century, while being a form of cross-curricular knowledge that inhabits computing contexts. ER activities have the potential to foster CT's unique skills because robotics requires students to interface with and explore algorithms, modules, sequences, loops, and variables (Sullivan et al., 2017). Bers (2021) expanded the concept of CT by considering it no longer just a problem-solving process, but rather an expressive process that can incentivise new modes of communication. There are numerous examples that require computational skills but are not related to the act of programming; Wing (2008) provided some related to everyone's daily life—think of sorting and classifying Lego pieces or the procedure of executing a recipe. The enhancement of such skills is thus necessary to help students consciously experience daily life and to form future citizens of a technology-driven society.

Aims of the Study

After a careful examination of the instruments identified in the literature, the RIQ scale (Dorotea et al., 2021) turned out to be particularly interesting for several reasons: it is a compact instrument (27 items) that has been validated with K–12 in-service teachers and aims to analyse the importance of dimensions such as teachers' knowledge of and interest in ER and self-confidence. The instrument, repurposed from Jaipal-Jamani and Angeli (2017), was initially submitted to a small sample (Piedade et al., 2020) and, following a timely review, was submitted to a larger population, responding positively to rigorous statistical and reliability measures. The second administration allowed the authors to start a statistical validation process with Portuguese teachers through EFA.

The RIQ is structured in four dimensions: F1, interest; F2, problem-solving; F3, working collaboratively; and F4, self-confidence and knowledge. It has been translated into Italian by means certified back translation and has been submitted to Italian teachers of all levels, from kindergarten to high school. As far as we know, there are no instruments for assessing interest and knowledge in ER whose validity and reliability have been confirmed by examining their psychometric properties with Italian teachers. There is thus a continuing need for a valid assessment instrument to measure interest, knowledge, and sense of self-efficacy for teaching through robotics.

To address this need, the entire psychometric validation process of the RIQ was performed in the present study. For this purpose, EFA (study 1) and CFA (study 2) were conducted. Furthermore, to test the instrument's ability to measure the construct of self-efficacy among Italian teachers and to assess the convergent validity of the RIQ, a further validated instrument in Italian, the teacher self-efficacy ('Questionario sull'Autoefficacia degli Insegnanti', QAI) questionnaire (La Marca & Di Martino, 2021), was jointly administered. Additionally, to establish criterion-related validity, the RIQ scores were compared between the different groups of teachers who participated in this survey.

Method

Participants

A total of 823 teachers at public Italian schools were recruited (age mean 48.63 years, SD = 9.22; 19.2% males; mean of years of seniority = 17.67 years, SD = 11.41). They worked in the following scholastic levels (indicating the grades for the different levels): kindergarten, age

3–5 years (n = 90, 10.9%); primary school, grade 1–5, age 6–10 years (n = 291, 35.4%); secondary school of the first order, grade 6–8, age 11–13 years (n = 185, 22.5%); and secondary school of the second order, grade 9–12, age 14–18 years (n = 257, 31.2%). Among the participants, 277 teachers (33.7%) had access to their teaching position with a diploma (based on Italian legislation prior to 2011), and 546 teachers (66.7%) started their professional careers on the basis of a bachelor's degree.

In relation to work areas, the teachers stated that their training was characterised as follows: teaching diploma (34.1%), primary education (7.9%), training in the humanities (20.2%), training in an expressive field (3.8%), and STEM (34.0%). Among these teachers, 22.7% declared having a further teaching specialisation. The participants worked in different Italian geographic areas: north (n = 229, 27.8%), centre and the island of Sardinia (n = 233, 28.3%), and south and the island of Sicily (n = 361, 43.9%). In the total sample, 68.8% of participants declared they did not have any experience in robotics.

We divided the participants randomly into two sub-samples to carry out two studies: specifically, for study 1 (EFA), sample 1 was composed of 412 participants (age mean = 48.79 years, SD = 9.15; 17.5% of males; mean of years of seniority = 18.08, SD = 11.33); for study 2 (CFA), sample 2 consisted of 411 participants (age mean = 48.47 years, SD = 9.29; 20.9% males; mean of years of seniority 17.25, SD = 11.49). Among the participants in study 1, 147 teachers (35.7%) had accessed their teaching position with a diploma (ante 2001), and 265 (64.3%) started their professional career on the basis of a bachelor's degree. Regarding study 2, 130 teachers (31.6%) accessed their teaching position with a diploma (ante 2001), and 281 (68.4%) started their professional career on the basis of a bachelor's degree. The detailed descriptive statistics for all participants, for sample 1 and sample 2, are presented in Table 1.

Non-probabilistic sampling was carried out; participants were recruited on a voluntary basis. Purposive sampling (Wolf et al., 2016) was applied, starting from the national list of schools furnished by the Italian Ministry of Education. Specifically, the survey was disseminated via a call to the managing head teachers at schools of all levels, randomly extracted from different geographical areas in Italy (north, central, south). The managers were informed of the scientific objectives of the survey, and after they had agreed to participate, all of their teaching staff received a link to the survey (administered by the digital platform LimeSurvey).

Table 1 Descriptive statistics of participants (N = 823)

n	**Total sample overall** 823	**Sub-sample 1 EFA** 412	**Sub-sample 2 CFA** 411
Gender (%)			
Male	158 (19.2)	72 (17.5)	86 (20.9)
Female	645 (78.4)	327 (79.4)	318 (77.4)
I prefer not to reply	20 (2.4)	13 (3.2)	7 (1.7)
Age in years [mean (SD)]	48.63 (9.22)	48.79 (9.15)	48.47 (9.29)
Teaching seniority in years [mean (SD)]	17.67 (11.41)	18.08 (11.33)	17.25 (11.49)
He/she is currently a teacher working in: [fr (%)]			
Pre-school (3–5 years)	90 (10.9)	47 (11.4)	43 (10.5)
Primary education (6–10 years)	291 (35.4)	144 (35.0)	147 (35.8)
First level high school (11–13 years)	185 (22.5)	88 (21.4)	97 (23.6)
Second level high school (14–19 years)	257 (31.2)	133 (32.3)	124 (30.2)
In which geographical area do you teach? [fr (%)]			
North Italy	229 (27.8)	119 (28.9)	110 (26.8)
Central Italy	233 (28.3)	128 (31.1)	105 (25.5)
South Italy	361 (43.9)	165 (40.0)	196 (47.7)
QAI_f1 Self-efficacy and teaching methods [mean (SD)]	4.91 (0.63)	4.92 (0.64)	4.90 (0.62)
QAI_f2 Self-efficacy and classroom practices/management [mean (SD)]	4.66 (0.71)	4.67 (0.71)	4.65 (0.71)
QAI_f3 Self-efficacy and teamwork [mean (SD)]	4.94 (0.65)	4.95 (0.67)	4.93 (0.62)
RIQ F1 Self-confidence and knowledge [mean (SD)]	2.82 (1.03)	2.77 (1.04)	2.87 (1.03)
RIQ F2 STEM and ER interest [mean (SD)]	4.12 (0.63)	4.11 (0.66)	4.14 (0.60)
RIQ F3 Teamwork [mean (SD)]	4.28 (0.55)	4.28 (0.53)	4.28 (0.56)
RIQ F4 Problem-solving [mean (SD)]	4.24 (0.54)	4.23 (0.54)	4.25 (0.53)

Instruments and Procedure

The participants were informed of the study's objectives and were assured that their responses would remain confidential (informed consent was obtained from all participants). In conducting the present research, all procedures performed were in accordance with the guidelines and ethical standards of the institutional research committee.

The RIQ (Dorotea et al., 2021) evaluates four dimensions through 27 items measured on a five-point Likert scale from 1 (strongly disagree) to 5 (strongly agree). The first dimension assesses *teachers' interest in robotics and technologies* (items 1–3; an example item is 'I find it interesting to learn about robots or robotics technology'); the second dimension is *problem-solving practices* (questions 4–11; an example of an item is 'I try new methods to solve a problem when one does not work'); the third is *working collaboratively* (assessed by items 12–15; an example item is 'I like to work with others to complete projects'); and the fourth dimension is *self-confidence and knowledge to use robotics in classroom activities* (items 16–27; an example item is 'I have sufficient knowledge about robotics for use in teaching and learning activities'). In their original Portuguese version (Dorotea et al., 2021), the Cronbach's alpha reliability was 0.950.

To outline the Italian version of the RIQ, we applied a back translation procedure, aiming to safeguard the cross-cultural equivalence in the translation of the items in different countries and cultures (Brislin, 1970). The RIQ in its Italian version can be found in the Appendix.

The teacher's self-efficacy was measured using the QAI (La Marca & Di Martino, 2021), an Italian validated instrument with 25 items. Participants' views about these dimensions were evaluated on a 6-point Likert scale, from 1 (strongly disagree) to 6 (strongly agree). The scale reliability was 0.959.

Data Analyses

Analyses were conducted by applying a multiple-step method. With sample 1, we carried out study 1, through the application of EFA. To solve the problem related to identifying the number of factors to retain in the EFA, we applied the scree plot method (Cattell, 1966) and parallel analysis (Horn, 1965). To detect the factor structure underlying the Italian version of the RIQ, EFA was applied using principal axis factoring, with the Oblimin rotation. We measured the appropriateness of these data using the Kaiser–Meyer–Olkin measure (KMO) and Bartlett's test of sphericity. We computed Cronbach's alpha to assess the reliability of factors (Chiorri, 2023).

In study 2, CFA was applied. The factorial structure highlighted by the EFA and hypothesised by the authors of the RIQ (Dorotea et al., 2021) (four correlated factors) was evaluated in sample 2. Additionally, Pearson's r correlation was computed between the scales of the RIQ instrument and the QAI (La Marca & Di Martino, 2021), to evaluate the convergent validity of the RIQ.

It might be appropriate to recall here that, in psychometrics, validity corresponds to the capability of an instrument to indeed measure what it intends to measure. It is not a unique concept, but a multidimensional one; in fact, it is possible to distinguish different types of validity which correspond to different methods of verification (Chiorri, 2023). Construct validity is given by the relationship of the actual measurement to the abstract dimension it is intended to measure (in our case, teachers' perceptions of ER). Among the several aspects considered by construct validity, there is convergent validity, which in our case was assessed by calculating the correlation between the factors of the RIQ and different measures (accomplished with an already validated instrument) of a related construct (specifically, teachers' self-efficacy, assessed by the QAI). To prove convergent validity, we assumed we would find a significant correlation between the RIQ factors and the QAI scale. This evaluation was applied by Pearson's r correlation coefficient, which is a parametric inferential bivariate statistical technique useful to quantify the relationship between two continuous variables in terms of magnitude and direction. This coefficient is standardised, ranging from -1 to $+1$, and is associated with a level of statistical significance, which, when it is lower than the critical alpha value ($p < 0.05$), represents the presence of a statistically significant correlation, or association, between the two variables (Chiorri, 2023).

Furthermore, to establish criterion-related validity, the RIQ scores were compared across different groups of teachers who participated in this investigation. These evaluations were made by applying multivariate analysis of variance (MANOVA), which is a parametric multivariate inferential statistical technique that compares the means of different groups of participants (Tabachnick & Fidell, 2007). MANOVA evaluates the differences between the means of groups identified on the basis of one or more factors, taking into account several continuous dependent variables; the latter are grouped in a weighted linear combination (in our case, the four factors of the RIQ). MANOVA evaluates whether the newly created combination differs in different groups identified by the factor (in our case, expertise in ER), essentially investigating whether the combined variable shows any systematic differences between the means of the groups.

The MANOVA results are associated with a level of statistical significance, which, when it is lower than the critical alpha value ($p < 0.05$), denotes the presence of statistically significant differences between groups. In MANOVA, potential differences between the averages of the four RIQ factors were evaluated in relation to the between-subjects factor defined as

Table 2 Descriptive statistics for RIQ items, EFA factor loadings, explained variance, and Cronbach's alpha reliability

	Mean	Standard deviation	Asymmetry	Kurtosis	Factor 1	Factor 2	Factor 3	Factor 4
19—I have sufficient knowledge to select the most appropriate robot for teaching and learning according to students' ages	2.61	1.23	0.32	− 0.94	0.943			
22—I have sufficient knowledge about block-based programming apps that can be used to teach programming concepts	2.64	1.20	0.28	− 0.90	0.916			
26—I feel confident about teaching computer science with different types of robotics	2.53	1.17	0.43	− 0.60	0.912			
16—I have sufficient knowledge about robotics for use in teaching and learning activities	2.81	1.19	0.15	− 0.98	0.908			
17—I have sufficient knowledge of coding as it applies to robotics	2.93	1.24	0.02	− 1.02	0.899			
18—I have sufficient knowledge of the engineering and design process as it applies to robotics	2.49	1.15	0.41	− 0.70	0.884			
20—I have sufficient knowledge to analyse the pedagogical potentialities of different type of robots	2.69	1.16	0.26	− 0.82	0.874			
21—I have sufficient knowledge about block-based programming apps that can be used to teach programming concepts	2.60	1.21	0.33	− 0.89	0.872			
24—I feel confident that I can help students when they have difficulties with robotics	2.85	1.19	0.01	− 0.99	0.828			
27—I feel confident that I can assess students' outcomes in robotics learning activities	2.79	1.25	0.12	− 1.10	0.811			
25—I feel confident that I can plan and design learning scenarios with robotics	2.84	1.21	0.07	− 1.02	0.765			
23—I feel confident that I can engage my students to participate in robotic-based projects	3.42	1.12	− 0.49	− 0.48	0.449			
3—I would use robotics in my classroom teaching	3.98	0.94	− 1.01	0.90		0.773		
1—I find it interesting to learn about robots or robotics technology	4.23	0.83	− 1.28	2.32		0.759		
2—I would like to use robotics to learn mathematics or science	4.05	0.90	− 1.14	1.57		0.751		
4—I like using scientific methods to solve problems	4.27	0.76	− 1.34	3.20		0.649		
9—I would like to learn more about careers that involve science, technology, engineering and mathematics	3.92	0.93	− 0.90	0.96		0.603		
5—I like using mathematical formulas and calculations to solve problems	4.00	0.89	− 1.10	1.67		0.577		
6—I think careers in science, technology, engineering or math are interesting	4.31	0.76	− 1.32	2.88		0.564		
15—I like to work with others to complete projects	4.31	0.67	− 1.05	2.77			0.807	
14—When working in teams, I ask my teammates for help when I run into a problem or do not understand something	4.38	0.59	− 0.71	1.95			0.780	
13—I like being part of a team that is trying to solve a problem	4.26	0.69	− 0.92	2.06			0.753	
12—I like listening to others when trying to decide how to approach a task or problem	4.19	0.68	− 1.00	3.10			0.560	
8—I make a plan before I start to solve a problem	4.18	0.69	− 0.74	1.24				0.723
11—I carefully analyse a problem before I begin to develop a solution	4.28	0.66	− 0.72	1.33				0.626
7—I use a step-by-step process to solve problems	4.19	0.71	− 1.02	2.52				0.552
10—I try new methods to solve a problem when one does not work	4.27	0.65	− 0.77	1.65				0.524
% explained variance					33.02	14.08	9.68	8.42
Cronbach's alpha reliability					0.971	0.887	0.835	0.818

factor 1, RIQ F1 Self-confidence and knowledge; factor 2, RIQ F2 STEM and ER interest; factor 3, RIQ F3 Teamwork; factor 4, RIQ F4 Problem-solving 'expertise in robotics' (experienced/inexperienced teachers; Tabachnick & Fidell, 2007).

The analyses were applied using the open-source software Jamovi (release 2.2.5) and Jasp (release 0.16.3).

Results

Study 1—EFA

In study 1, we applied the EFA (principal axis factoring) with Oblimin rotation (KMO measure of sampling adequacy = 0.943; Bartlett's test of sphericity chi-square = 9647; df = 351; $p < 0.001$). The four components explained 65.2% of the total variance, and all items had a component load of 0.40 or above (Table 2). The internal consistency was determined by Cronbach's alpha, and it showed good values (factor 1, 0.971; factor 2, 0.887; factor 3, 0.835; factor 4, 0.818). In Table 2, we can observe that the factorial structure of the Italian version of the RIQ is consistent with the four correlated factors identified by the authors of the instrument in their original Portuguese version (Dorotea et al., 2021).

Study 2—CFA

In the second sample, CFA (estimator diagonally weighted least squares, DWLS, robust method) (Rhemtulla et al., 2012) was applied; we examined the data fit in relation to the a priori model (four correlated factors) specified by the authors of the RIQ and highlighted in the previous EFA. To assess the model, multiple indices were considered: ratio of chi-square and its degrees of freedom defined as being good if it is below three (Schermelleh-Engel et al., 2003); comparative fit index (CFI) for which higher than 0.90 is considered suitable (Byrne, 2001); and the indices root mean square error of approximation (RMSEA) and standardised root mean square residual (SRMR), for which values lower than 0.08 are designated as satisfactory fit (Hu & Bentler, 1999). The CFAs applied showed good fit indices (see Table 3) and significant parameter estimations, confirming the four-factor structure of the questionnaire in this Italian version (see Table 4).

Table 3 CFA fit indices

Index	Value
Chi-square factor model (X^2, df, p)	441.191, df = 318, $p < 0.001$
Ratio of chi-square and its degrees of freedom	1.387
Comparative fit index (CFI)	0.994
Root mean square error of approximation (RMSEA)	0.031
RMSEA 90% CI lower bound	0.023
RMSEA 90% CI upper bound	0.037
Standardised root mean square residual (SRMR)	0.063

Assessment of Validity: Convergent and Criterion-Related

The scales of the RIQ instrument were correlated with a measure of teacher self-efficacy (QAI; La Marca & Di Martino, 2021) to appraise the convergent validity of the RIQ. The linear correlations (Pearson's r) between the assessed variables highlighted and confirmed the relationships between the dimensions examined, consistent with the literature (Table 5). Indeed, as assumed on the basis of previous studies on this topic, the three factors of the QAI (evaluating self-efficacy in teachers) showed systematic, direct, and statistically significant linear correlations ($p < 0.05$) with each factor evaluated by the RIQ (specifically, the closer the value of the correlation coefficient approached to one in absolute value, the closer the relationship between the two variables considered). This means that as the scores obtained in the QAI increased, the scores obtained in the measurements carried out with the four factors of the RIQ also increased proportionally (or else, as the scores obtained in the QAI decreased, the scores obtained in the measurements carried out with the four factors of the RIQ also decreased proportionally).

Additionally, to estimate criterion-related validity, the scores of the RIQ factors were compared across different groups of teachers who participated in this investigation; we assessed the differences/similarities in the mean scores of the RIQ by applying MANOVA (Table 6). In this multivariate statistical analysis, we considered as a between-subjects factor the variable *expertise in robotics* (experienced/inexperienced teachers), identified by the self-evaluation in two items of the questionnaire.

The findings highlighted a significant multivariate effect of *expertise in robotics* (Wilk's lambda = 0.550; $F = 167.239$; df = 4, 818; $p < 0.001$; partial eta squared = 0.450); the significant effect was confirmed at the univariate level (see Table 6). More specifically, we observed a significant effect of *expertise in robotics* for all four dimensions of the RIQ, in which teachers with experience in robotics showed scores significantly higher than their colleagues without experience (RIQ factor 1: $F = 646{,}385$; df = 1, 821; $p < 0.001$; partial eta squared = 0.441; RIQ factor 2: $F = 139.626$; df = 1, 821; $p < 0.001$; partial eta squared = 0.145; RIQ factor 3: $F = 19.969$; df = 1, 821; $p < 0.001$; partial eta squared = 0.024; RIQ factor 4: $F = 52.315$; df = 1, 821; $p < 0.001$; partial eta squared = 0.060) (Table 6). These data emphasised that the teachers showed significant differences in their scores in the RIQ based on their experience in ER. These differences between means are

Table 4 CFA factor loadings and parameter estimates

Factor	Item	Estimate	Std. error	*z*-value	*p value*	95% confidence interval		R^2
						Lower	Upper	
Factor 1	19	1.077	0.037	28.766	< 0.001	1.003	1.150	0.768
	22	1.087	0.037	29.585	< 0.001	1.015	1.159	0.804
	26	1.041	0.038	27.354	< 0.001	0.966	1.115	0.799
	16	1.046	0.038	27.760	< 0.001	0.972	1.120	0.745
	17	1.008	0.039	25.662	< 0.001	0.931	1.085	0.718
	18	0.906	0.040	22.813	< 0.001	0.828	0.984	0.656
	21	1.026	0.039	26.593	< 0.001	0.951	1.102	0.725
	20	0.980	0.042	23.284	< 0.001	0.898	1.063	0.693
	23	0.817	0.048	16.881	< 0.001	0.722	0.911	0.524
	24	1.077	0.037	28.900	< 0.001	1.004	1.150	0.797
	25	1.005	0.041	24.534	< 0.001	0.925	1.085	0.718
	27	1.065	0.036	29.378	< 0.001	0.993	1.136	0.807
Factor 2	1	0.562	0.047	12.071	< 0.001	0.471	0.654	0.566
	2	0.605	0.048	12.497	< 0.001	0.510	0.700	0.535
	3	0.727	0.048	15.260	< 0.001	0.634	0.821	0.684
	4	0.560	0.044	12.764	< 0.001	0.474	0.646	0.544
	5	0.492	0.049	9.982	< 0.001	0.395	0.588	0.352
	6	0.431	0.039	11.116	< 0.001	0.355	0.507	0.366
	9	0.542	0.049	11.038	< 0.001	0.446	0.638	0.413
Factor 3	12	0.454	0.048	9.443	< 0.001	0.360	0.548	0.479
	13	0.647	0.034	18.917	< 0.001	0.580	0.714	0.846
	14	0.427	0.040	1.587	< 0.001	0.348	0.506	0.516
	15	0.568	0.044	12.841	< 0.001	0.481	0.655	0.705
Factor 4	7	0.406	0.046	8.865	< 0.001	0.316	0.496	0.380
	8	0.539	0.045	12.109	< 0.001	0.452	0.627	0.640
	10	0.531	0.040	13.341	< 0.001	0.453	0.609	0.680
	11	0.494	0.038	12.898	< 0.001	0.419	0.569	0.604

factor 1, RIQ F1 Self-confidence and knowledge; factor 2, RIQ F2 STEM and ER interest; factor 3, RIQ F3 Teamwork; Factor 4, RIQ F4 Problem-solving and computational thinking

Table 5 Pearson's *r* correlations

		QAI_f1 Self-efficacy and teaching method	QAI_f2 Self-efficacy and classroom practices/management	QAI_f3 Self-efficacy and teamwork	RIQ F1 Self-confidence and knowledge	RIQ F2 STEM and ER interest	RIQ F3 Teamwork
QAI_f2 Self-efficacy and classroom practices/management	*r*	0.769**					
QAI_f3 Self-efficacy and teamwork	*r*	0.752**	0.671**				
RIQ F1 Self-confidence and knowledge	*r*	0.292**	0.277**	0.123**			
RIQ F2 STEM and ER interest	*r*	0.233**	0.165**	0.153**	0.485**		
RIQ F3 Teamwork	*r*	0.389**	0.329**	0.387**	0.186**	0.501**	
RIQ F4 Problem-solving	*r*	0.389**	0.291**	0.307**	0.239**	0.539**	0.541**

**$p < 0.01$

Table 6 Univariate effects highlighted in the MANOVA for the variable *expertise in robotics*

Factor	Dependent variable	df (between, within)	*F*	*p* value	Partial eta squared
Expertise in robotics	RIQ F1 Self-confidence and knowledge	1, 821	646.385	< 0.001**	0.441
	RIQ F2 STEM and ER interest	1, 821	139.626	< 0.001**	0.145
	RIQ F3 Teamwork	1, 821	19.969	< 0.001**	0.024
	RIQ F4 Problem-solving	1, 821	52.315	< 0.001**	0.060

df degrees of freedom

** $p < 0.01$

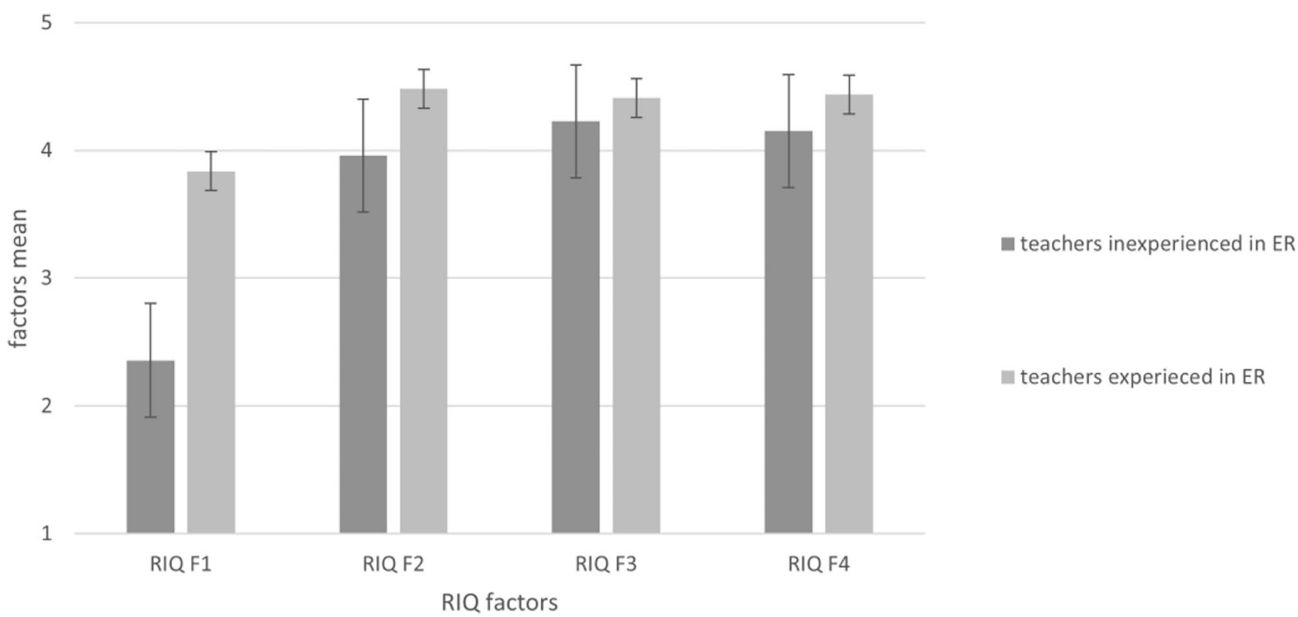

Fig. 2 Means in the RIQ factors in relation to the variable *expertise in robotics.* Note: RIQ F1: Self-confidence and knowledge; RIQ F2: STEM and ER interest; RIQ F3: Teamwork; RIQ F4: Problem-solving

graphically represented in Fig. 2, where we can observe that the experienced teacher in ER showed statistically significantly higher scores for factors of the RIQ (F1, Self-confidence and knowledge; F2, STEM and ER interest; F3, Teamwork; and F4, Problem-solving) than their inexperienced colleagues (see Table 6 and Fig. 2).

Discussion and Conclusions

The main aim of this study was to validate in the Italian context the RIQ, an instrument developed and validated in Portugal (Dorotea et al., 2021). The factorial analyses (exploratory and confirmatory) showed that the four dimensions of the RIQ are also identifiable in relation to Italian teachers and present high-reliability coefficients, showing the high internal consistency of the instrument. During our study, an effort was also made to analyse the levels of interest, self-confidence, and knowledge in the use of robotics by teachers at different educational grade levels and from different Italian regions, to promote CT at school; furthermore, a focus was placed on teachers' interest in collaborative work and problem-solving.

Only a few minor differences with respect to the original instrument were highlighted; in fact, as can be seen in the "Results" section, some items of the questionnaire were positioned in different factors. Specifically, factor 2 (RIQ F2 STEM and ER interest) included a total of seven items, compared to the three in the original instrument (questions 1, 2, and 3); four further items relating to the assessment of problem-solving (questions 4, 5, 6, and 9) were included in this factor. This differentiation could be related to the different socio-cultural context in which the instrument was administered. Specifically, we may suppose that this distinction may be linked to the fact that ER in Italy has mainly—and for a long time—only concerned STEM disciplines, with a connotation typically aimed at problem-solving. On the other hand, the factorial structures of the remaining factors relating to teamwork (factor 3 = RIQ F3) and to self-confidence and knowledge (factor 1 = RIQ F1) appeared the same in the Italian and Portuguese versions.

Regarding the relationship between the factors identified and the other variables, it is evident that having or not having previous experience with robotics promoted significant differences between the factor averages. Specifically, it is highlighted that teachers with expertise in ER showed statistically significant differences in all four factors (RIQ F1, Self-confidence and knowledge; RIQ F2, STEM and ER interest; RIQ F3, Teamwork; RIQ F4, Problem-solving), with considerably higher scores than those who claimed to have no experience. This confirms the validity of the instrument in its ability to distinguish teachers with different levels of expertise in the four identified dimensions. Overall, it appears that the findings show a good adaptation of the scale used (Dorotea et al., 2021; Jaipal-Jamani & Angeli, 2017) to the socio-cultural context of the study.

Having to consider the weaknesses of this work, we must remember that the sampling was carried out on a national scale but was not probabilistic; indeed, participation was on a voluntary basis, linked to the involvement of the educational institutions of the different school orders. This may represent not only a limitation, however, but also a strength of the research, because it allowed us to reflect and assess the general interest in these dimensions among all teachers, both experienced and inexperienced in ER. It should also be mentioned that this instrument was based on teachers' self-assessments so that the results are closely linked to the individual's perception, sense of self-efficacy, and ability to consistently self-assess. Future developments of this study could consider implementing and looking at/comparing parallel assessments related to objective measures of knowledge and skills in ER.

We can highlight several strengths of this work. First, the RIQ could be useful to those interested in grasping the complexity of teachers' attitudes towards robotics. In addition to the fact that, in the Italian panorama, no instrument has been found that has been validated with a careful verification of the psychometric properties and that measures the explicit constructs, we believe that this questionnaire can adequately investigate these dimensions and reveal the complexity of the interaction between the different aspects of interest, from teamwork to self-confidence.

Just as there is evidence suggesting that the use of teacher self-efficacy assessment tools can help improve their job performance and facilitate their professional development (i.e. Tschannen-Moran & Hoy, 2001), it is reasonable to believe that a tool such as the RIQ could similarly enhance teachers' preparation and enable them to acquire new skills and more effective teaching strategies. The RIQ scale, in this context, could find a domain of use by those interested in pre- and in-service teacher training. The instrument could be considered as a valid support for assessment within specific training courses. In a research training design, *pre-* and *post-*surveys could measure, on the one hand, the expertise of teachers at the end of the curricula in general times, and, on the other, the more specific changes in the multiple dimensions investigated: interest, knowledge, self-confidence, and transversal skills such as teamwork and problem-solving. Results from the application of the RIQ could aid in designing and defining the content of teacher training interventions based on the identified shortage areas. On one hand, the test provides us with the detected proficiency levels and varying competencies across different dimensions. This could enable the selection of participants and allow the tailoring of training for different groups based on their specific needs (e.g. level of pedagogical support, types of activities). The use of the scale could metacognitively suggest to trainers and teachers which aspects of the experience need to be strengthened, thus encouraging forms of self-assessment. School headmasters would also have support in choosing which courses would better promote the expected results in their schools.

The tool is also in line with the priorities expressed in the recent Digital Education Action Plan (2021 – 2027), as it reinforces the need to stimulate further studies on digital technologies in learning and data collection that would be treated as an input for the very definition of educational policies. The theoretical framework of reference is increasingly attracting international attention, both for its innovative nature and for being in constant and continuous evolution. The interest in such issues in Italy is expanding, so the investment in training courses on ER could arouse considerable interest and success, favouring a congruous number of new empirical studies to assess the potential of such practices in Italian schools. A tool that assesses knowledge, transversal skills, and self-confidence would support constant monitoring of teachers' attitudes and aptitudes, fostering educational actions to enhance innovative practices in all educational institutions, at all levels.

Appendix. Versione italiana del Questionario di Interesse in Robotica (RIQ, Robotics Interest Questionnaire)

Esprimere il proprio grado di accordo in relazione alla seguente scala Likert:

1—Fortemente in disaccordo; 2—In disaccordo; 3—Né in disaccordo né d'accordo; 4—D'accordo; 5—Fortemente d'accordo.

D1	Trovo interessante conoscere i robot o la tecnologia robotica
D2	Mi piacerebbe usare la robotica per imparare la matematica o le scienze
D3	Userei la robotica nel mio insegnamento in aula
D4	Mi piace usare metodi scientifici per risolvere i problemi
D5	Mi piace usare formule e calcoli matematici per risolvere i problemi
D6	Penso che le carriere in ambito scientifico, tecnologico, ingegneristico o matematico siano interessanti
D7	Uso un processo passo-passo per risolvere i problemi
D8	Elaboro un piano prima di iniziare a risolvere un problema
D9	Mi piacerebbe saperne di più sulle carriere che coinvolgono la scienza, l'ingegneria tecnologica e la matematica
D10	Provo nuovi metodi per risolvere un problema quando uno non funziona
D11	Analizzo attentamente un problema prima di iniziare a sviluppare una soluzione
D12	Mi piace ascoltare gli altri quando cerco di decidere come affrontare un compito o un problema
D13	Mi piace far parte di un team che sta cercando di risolvere un problema
D14	Quando lavoro in team, chiedo aiuto ai miei compagni di squadra se mi imbatto in un problema o non capisco qualcosa
D15	Mi piace lavorare con gli altri per completare i progetti
D16	Conosco a sufficienza la robotica per l'uso in attività di insegnamento e apprendimento
D17	Conosco a sufficienza il coding che si applica alla robotica
D18	Conosco a sufficienza il processo di ingegneria e progettazione che si applica alla robotica
D19	Ho conoscenze sufficienti per selezionare il robot più appropriato per l'insegnamento e l'apprendimento in base all'età degli studenti
D20	Ho conoscenze sufficienti per analizzare le potenzialità pedagogiche di diversi tipi di robot
D21	Conosco a sufficienza le app di programmazione block-based che possono essere utilizzate per insegnare concetti di programmazione
D22	Sono sicuro di avere le competenze necessarie per utilizzare la robotica per l'istruzione in classe
D23	Sono sicuro di poter coinvolgere i miei studenti a partecipare a progetti basati sulla robotica
D24	Sono sicuro di poter aiutare gli studenti quando hanno difficoltà con la robotica
D25	Sono sicuro di poter pianificare e progettare scenari di apprendimento con la robotica
D26	Mi sento sicuro nell'insegnamento dell'informatica con diversi tipi di robotica
D27	Sono sicuro di poter valutare i risultati degli studenti nelle attività di apprendimento della robotica

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Author Contribution M.A., G.B., A.M: Made substantial contributions to conception and design, or acquisition of data, or analysis and interpretation of data; Involved in drafting the manuscript or revising it critically for important intellectual content; Given final approval of the version to be published; Agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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Data Availability The datasets for this study are available from the corresponding author on reasonable request.

Declarations

Ethics Approval and Consent to Participate The studies involving human participants were reviewed and approved by the University of Cagliari (Italy). Written informed consent to participate in this study was provided by the participants.

Conflict of Interest The authors declare no competing interests.

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