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Regular Article

The Italian Version of the Robotics Learning Self-Efficacy Scale (RLSES-IT): Assessment of psychometric features in a sample of young students

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ABSTRACT

This study evaluated the psychometric characteristics in the Italian context of the Robotics Learning Self-Efficacy Scale (RLSES). A sample of 353 young students attending an educational robotics (ER) course in their primary or secondary schools completed the assessment battery, including the RLSES and a validated questionnaire inquiring about students' self-efficacy. Regarding the RLSES, an exploratory factor analysis and then a confirmatory factor analysis were applied on two random subsamples. The findings highlighted two reliable factors; the convergent and criterion-oriented validity were also established. This work demonstrates that the Italian RLSES can be considered a valid and reliable tool for evaluating students' self-efficacy in robotics learning and supporting the teachers' actions in ER teaching.

1. Introduction

Educational robotics (ER) has recently made its way into academic research; in fact, a significant and growing amount of scientific research can be identified (Akgun & Atici, 2023). Several studies have highlighted how robotics in education can add value to the learning process. For these reasons, even schools, within the framework of classroom teaching, have become interested in ER regarding the development of soft skills such as collaboration in problem-solving processes (Taylor & Baek, 2018), the understanding of concepts related to science, technology, engineering, and mathematics (STEM) areas (Sullivan & Bers, 2018; Taylor & Baek, 2018), the promotion of higher-order thinking skills (Atman Uslu et al., 2022), and the development of computational thinking (Aristawati et al., 2018; Chen et al., 2017).

ER, anchored in Papert's (1980) ideas on constructionism, is based on a more practical approach to education that involves building one's own networks of meaning through a concrete object with which to reflect (Harel and Papert, 1991) and build knowledge. A recent meta-analysis (Sun & Zhou, 2023) showed that ER activities have a positive effect on both the development of essential skills (knowledge, concepts, and practice) and generative skills (computational thinking, learning skills, and psychological tendencies). As a result of the international interest and investment by individual institutions in such practices, there is a need to stimulate studies on instructional design that include educational robots. However, the mere integration of a robot in an educational context produces no added value in terms of educational outcomes if it is not consciously handled as an instructional design tool (Wu et al., 2015). There are many approaches in the use of robotics in schools: It can be considered as education with robotics when the robotic tool acts as a didactic mediator through which one builds learning in different subject areas, or it can be configured as a discipline in its own right. Due to the growing presence of ER in schools, there is an increasing need for research that explores its educational implications in greater depth. In particular, it is important to understand how to evaluate ER activities effectively and to rely on valid assessment tools (Marcianò, 2017). These tools should be capable of capturing the various dimensions of ER learning in schools, in order to promote the conscious integration of robots into teaching and learning processes. At the time of this writing, an evaluation tool for ER workshops that meets school requirements and takes into account the different project proposals, objectives, and goals to be achieved or the cognitive profiles of the students in focus does not appear to exist. In this sense, the evaluation of such educational work has been delegated, at least in Italy, to curricular and disciplinary evaluation. Beyond the importance of evaluative observation during workshops, it is necessary to think of and validate instruments decontextualized from the specific learning

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situation that are capable of verifying the enhancement of the key competences in ER, as well as the didactic objectives. Among the variables involved in learning processes involving ER, as we will see more in the next section, students' sense of self-efficacy in learning "about" and "with" robotics would seem to play a key role. Therefore, the ability to measure students' sense of self-efficacy involved in robotics activities could provide important information to teachers and, more generally, to all educational agencies that are working to ensure that, through the systematic integration of robotics practice, the study of computational thinking in school can be fostered. Thus, the present work sought to validate in Italian an instrument called the Robotics Learning Self-Efficacy Scale (RLSES) with students of all levels of public schools in Italy. Self-efficacy, a concept introduced by Bandura (1977), refers to an individual's belief in their ability to succeed in specific tasks or situations. As will be further discussed in the following sections, self-efficacy plays a crucial role in students' learning processes, including those involving ER.

2. Educational robotics learning

School educators, in connection with the increasing focus on technology and artificial intelligence, have become interested in learning about or through robotics. Related studies have investigated the impact of the ER practice on learning processes, focusing on multiple aspects, from developing creativity (Afari & Khine, 2017) to increasing learning motivation (Mubin et al., 2013). Equally important is the role of robotics to foster the development of digital skills (Alimisis, 2013; Heinmäe et al., 2022) and reflective thinking skills (Pakman et al., 2023). Learning robotics, in this sense, is becoming one of the privileged channels for technology education as it involves not only aspects of computer programming but also the design and construction of various hardware components. Hence, its inherent laboratory character is well suited to the structuring of flexible learning environments, where learning by doing and collaborative learning support the process of knowledge construction and problem-solving (Menekse et al., 2017). Through ER activities, students engage in interdisciplinary collaboration that fosters meaningful learning and the development of integrated knowledge structures.

Although some research has shown the potential of educational robots, the definition of the specific educational objectives that might accompany the design and implementation of ER activities is not yet unanimously agreed upon. The scientific literature has nevertheless demonstrated that using robots in education can affect multiple developmental domains, including cognitive, linguistic, and social areas (Toh et al., 2016). Some scholars (e.g., Tsai et al., 2021) have taken inspiration from Bloom et al., 1956 taxonomy of educational goals, identifying five relevant aspects in ER activities: (a) conceptual understanding; (b) technical performance; (c) application; (d) analysis; and (e) collaboration. These goals can serve not only as a framework for instructional design but also as a valuable resource for teacher training and for the development of robotics assessment tools.

These learning objectives might not only guide instructional design on robotics learning but also be a useful support in the context of teacher training in the design of ER activities and the development of robotics learning evaluation tools. Furthermore, several researchers have verified how integrating ER into the learning process can stimulate the development of students' computational thinking and self-efficacy (Massaty et al., 2020; Shang et al., 2023). In the same direction, some studies have found an increase in students' self-efficacy in programming following the performance of ER activities (Güleryüz, 2022; Theodoropoulos et al., 2018; Yıldız & Sadi Seferoğlu, 2021). Specifically, students have reported that they enjoy computer science more following ER and are more confident in their programming skills.

Self-efficacy is an individual's perception of their own capabilities in achieving a specific goal (Bandura, 1977). Self-efficacy is an important concept in education as it contributes not only to students' behaviour and motivation but also to the degree of commitment students demonstrate toward their studies (Zimmerman, 2000). Having a strong sense of self-efficacy promotes high levels of motivation, academic success, and the development of an intrinsic interest in school subjects (Bandura & Schunk, 1981). Developing self-efficacy beliefs in robotics is possible when pupils have direct experiences of competence. For instance, engaging in an ER activity and finding success can increase levels of self-efficacy, as it provides real evidence of what the student can do successfully; conversely, direct experiences of failure are the most common source of students' decreased confidence (Ford et al., 2023).

Students' belief that they have been successful in a previous exposure to robotics activities leads them to be more confident in their ability to perform that task in the future and thus increases their confidence (Ahn et al., 2016; Ford et al., 2023). Ford et al. (2023), carrying out a study on students' beliefs about failures in robotics, highlighted the lack of studies on the sources of self-efficacy in robotics. In essence, we assert that personal cognitions such as self-efficacy shape how students interpret their experiences with ER. Thus, the need for an instrument capable of assessing self-efficacy in robotics learning is apparent. In the broader literature, self-efficacy is often discussed in terms of general self-efficacy, which refers to a person's overall belief in their ability to cope with a variety of challenging situations (Bandura, 1977), and domain-specific self-efficacy, which concerns confidence in one's ability to perform in a specific task or context (Zimmerman, 2000). In the context of robotics education, robot-use self-efficacy has emerged as a specific construct, referring to students' or teachers' perceived ability to successfully engage in robotic programming, design, or collaborative tasks (Yanış & Yürük, 2020; Ford et al., 2023). While general self-efficacy is a predictor of global academic outcomes, domain-specific measures—such as robotics-related self-efficacy—have shown stronger predictive power for performance in targeted STEM activities. For this reason, the RLSES was chosen as a domain-specific instrument capable of capturing nuances in students' perceived competencies in ER.

An example of an instrument designed to assess self-efficacy in ER is the RLSES questionnaire, developed in Taiwan (Tsai et al., 2021). The original version included 32 items, which were reduced to 16 through factor analysis, organized into five subscales: Comprehension, Practice, Analysis, Application, and Collaboration. The instrument demonstrated strong statistical validity and reliability. A two-level construct (2 x 3) was confirmed through further regression analysis, indicating that self-efficacy in ER practice and comprehension predicted self-efficacy in analysis, application, and collaboration.

The present study focused on validating the RLSES for use with Italian students. In the Italian context, there was previously no assessment tool for self-efficacy in robotics learning that met established criteria for validity and reliability. This work builds on the shared perspective (Babazadeh & Negrini, 2022; Toh et al., 2016; Tsai et al., 2021) that a valid instrument can effectively support the evaluation of robotics learning, offering researchers, teachers, and educators a means to assess students' learning outcomes and sense of efficacy during ER activities.

3. Research aim

Referring to the promising value of the RLSES, besides its present unavailability in the Italian context, the main purpose of this work was to investigate the psychometric properties of the Italian version of the RLSES in a sample of students attending a scholastic project in ER in either the final 2 years of primary school or junior or senior secondary schools. The Italian version might be useful in research and educational domains, offering teachers and researchers an effective instrument to measure the level of students' self-efficacy regarding the ER activities carried out. The tool is interesting mainly because it is compact (consisting of 16 items) and easy to administer in school settings.

To accomplish our research aim, the factorial structure of the scale was assessed in two stages: first by an exploratory factor analysis (EFA) carried out with subsample 1, and then by a confirmatory factor analysis (CFA) applied to subsample 2. Also, the reliability of the instrument was assessed. Additionally, the convergent validity of the instrument was evaluated by the consideration of the linear correlations of RLSES dimensions with an instrument validated in the Italian context, assessing perceived scholastic self-efficacy, the Italian *Scala di Autoefficacia Scolastica Percepita* (Pastorelli & Picconi, 2001). The rationale for this choice is grounded in Bandura's social cognitive theory (1977), which posits that self-efficacy beliefs, whether general or domain-specific, are part of a broader system of perceived capability that affects learning and performance. We expected the RLSES, as a domain-specific measure, to correlate positively with a validated general scholastic self-efficacy scale, reflecting convergent validity. To this end, we selected the Pastorelli's and Picconi's scale (2001) as established and culturally appropriate instrument widely used in the Italian context. This measure provides a reliable estimate of students' perceived general academic competence, allowing us to assess the extent to which the RLSES aligns with a theoretically related construct.

Concerning criterion-oriented validity, the scores of the RLSES factors were evaluated in terms of the number of hours spent in the ER project. The rationale for this choice is that students who spent more time in the ER project likely had more opportunities to build robotics-related self-efficacy. Therefore, we suppose that RLSES scores might be related to the number of hours spent in the ER project, using this variable to support the scale's criterion-oriented validity.

4. Method

4.1. Participants

A total of 353 students (males n = 185, 51.4 %) attending wholly 34 public Italian schools (primary school: n = 105, 29.2 %; junior secondary schools: n = 162, 45 %; senior secondary schools: n = 93, 25.8 %) were recruited in different Italian geographical areas: 45 students (12.7 %) attended schools in northern areas of Italy; 41 students (11.6 %) attended schools in central areas of Italy; 267 students (75.6 %) lived in the southern Italian regions. The participants had a mean age of 12.65 years (SD = 2.39, range 9–19 years); they spent an average of 22.10 h (SD = 15.08) on the scholastic ER project.

We randomly split the participants into two subsamples to conduct analyses for studies 1 and 2. The two subsamples did not show any significant differences regarding sociodemographic variables evaluated in the assessment battery.

data collection was conducted via non-probabilistic sampling, based on the availability and willingness of participation of the school managers, teachers, and students (with the consent of their parents) engaged in the ER projects. The study was completed in 2023, conducted in line with the Declaration of Helsinki. The assessment battery was approved by the Ethical Committee of the University of Cagliari (approval n 0276446). The descriptive statistics of the assessed variables are reported in Table 1.

Table 1
Descriptive statistics for sociodemographic data and for scales administered, regarding the total sample and sub-samples.

Variables	Total sample	Sub sample Study 1 - EFA	Sub sample Study 2 - CFA
n	353	176	177
Gender – male - frequency (%)	181 (51.2)	96 (54.2)	85 (48.3)
Age - mean (SD)	12.6 (2.4)	12.5 (2.5)	12.7 (2.3)
Geographic Italian areas - frequency (%)			
Northern and central Italian areas	123 (34.9)	66 (37.3)	67 (38.1)
Southern and central Italian areas	230 (65.1)	111 (62.7)	109 (61.9)
Type of school – frequency (%)			
Primary school	105 (29.7)	57 (32.2)	48 (27.3)
Attending Fourth year - frequency	19	12	7
Attending Fifth year - frequency	86	45	41
Junior secondary school	155 (43.9)	71 (40.1)	84 (47.7)
Attending First year - frequency	21	14	7
Attending Second year - frequency	76	34	42
Attending Third year - frequency	58	23	35
Senior secondary school	93 (26.4)	49 (27.7)	44 (25)
Attending First year - frequency	10	6	4
Attending Second year - frequency	31	12	19
Attending Third year - frequency	27	15	12
Attending Fourth year - frequency	10	8	2
Attending Fifth year - frequency	15	8	7
Hours dedicated to the ER project - mean (SD)	22.1 (15.1)	23.2 (14.8)	21.0 (15.4)
How much did you like the educational robotics project or laboratory? (range 1–5)	4.5 (0.7)	4.5 (0.7)	4.5 (0.7)
How much do you think educational robotics could be useful to you in your life? (range 1–5)	4.0 (1.0)	4.1 (0.9)	3.9 (1.1)
How much would you like to participate in another ER project or lab? (range 1–5)	4.3 (0.8)	4.3 (0.9)	4.4 (0.8)
The teacher of the educational robotics laboratories was: frequency (%)			
A teacher who teaches in another school	14 (4.0)	6 (3.4)	8 (4.5)
A teacher who teaches in my class	232 (65.7)	112 (63.3)	120 (68.2)
A teacher from my school who teaches another class	81 (22.9)	48 (27.1)	33 (18.7)
An expert in educational robotics	18 (5.0)	9 (5.1)	9 (5.1)
I don't know	8 (2.3)	2 (1.1)	6 (3.4)
Did you need the support of a teacher during the ER project? - Yes - frequency (%)	74 (21.0)	31 (17.5)	43 (24.4)
Perceived Scholastic Self-Efficacy Scale - mean (SD)	69.6 (12.7)	70.5 (14.3)	68.8 (10.9)
RLSES – F1 - mean (SD)	3.4 (0.7)	3.5 (0.8)	3.4 (0.7)
RLSES – F2 - mean (SD)	3.1 (0.9)	3.1 (0.9)	3.0 (0.9)

4.2. Materials and procedure

The RLSES was translated into Italian using the procedure of translation-back translation. Specifically, to create the Italian version of this instrument, first, two independent academics translated the scale from English to Italian and then found agreement on a shared version. The shared document of the RLSES had been back-translated by a bilingual scholar with broad expertise in the psychological field. The back translation was almost equal to the initial version (Brislin, 1970, 1986). As a final action, the Italian RLSES items were appraised by two additional experts in the ER discipline, who evaluated the clarity of each item. The Italian version of the RLSES is reported in Appendix A.

The research protocol was organized into specific sections.

The first section evaluated the sociodemographic and scholastic aspects (age, gender, level of schooling, geographic area, hours spent in the ER scholastic project, features of activities in the ER project, satisfaction expressed by the student, and perceived level of usefulness in the ER activities carried out).

The second section of the assessment battery referred to the presentation of the Italian version of the original RLSES devised by Tsai et al. (2021). This scale was based on Bloom's taxonomy of educational objectives and assessed students' self-efficacy for learning robotics. The authors developed 16 items (evaluated on a Likert scale of 5 points, including 1 – not confident at all to 5 – very much confident); they identified in the RLSES five dimensions: *Practice, Analysis, Application, Collaboration, and Comprehension*.

The *Practice* dimension assessed students' confidence in preparing a hands-on robotics task. A representative item is: "I can build a circuit for a robot."

The *Application* dimension measured students' confidence in applying their robotics knowledge to solve problems; for example, "I can apply robotics knowledge in my daily life."

The *Collaboration* dimension aimed to evaluate students' confidence in collaborating with peers while learning robotics in schoolrooms; for example, "I can present my ideas clearly in a robotics classroom."

The *Comprehension* dimension considered the assessment of students' confidence in understanding conceptual knowledge whilst acquiring robotics, with a representative item: "I can link robotics concepts with other learning subjects."

The *Analysis* dimension evaluated students' confidence in investigating the problems concerning robotics while studying robotics, with a representative item: "I can evaluate several robotic solutions for solving a problem."

The reliability of the original instrument (Cronbach's alpha) for the overall scale was good (0.87). In Italian sample, the reliability for the overall instrument was 0.90.

The third section of the assessment battery included the *Perceived Scholastic Self-Efficacy Scale (Scala di Autoefficacia Scolastica Percepita)* created by Pastorelli and Picconi (2001), presented to measure students' self-efficacy at school. It is used to assess young students' beliefs about their general abilities to study certain subjects, regulate their motivation and performance of activities at school, and to seek and find learning support. The scale has 19 items assessed with a Likert scale of 5 points (from 1 – not at all capable - to 5 – very capable). The Cronbach's alpha reliability index in the validation sample was good (α = 0.85); in our sample, the reliability was 0.91.

4.3. Statistical and data analyses

The statistical analyses occurred in different stages. First, the descriptive statistics of all assessed variables were applied; the features of the data distribution were evaluated to define the next steps of data analysis. Then, the sample was randomly divided in two comparable sub-samples: sub-sample 1 underwent an application of EFA (study 1); sub-sample 2 was used to carry out the CFA.

In sub-sample 1 (Study 1), the Kaiser-Meyer-Olkin test to evaluate the suitability of the data to conduct the EFA (Dziuban & Shirkey, 1974; Kaiser, 1970), and Barlett's (1954) test were employed. Scree plot criteria and parallel analysis were used to define the number of factors to retain in the Italian version of the RLSES (two factors). The minimum residual method of extraction was applied (Harman & Jones, 1966), with oblique promax rotation.

In the following phase of analysis (Study 2), a CFA was carried out on the second random sub-sample; as a method of estimation the unweighted least squares (ULS) was applied. We evaluated the fit of two models: model 1, considering a single factor solution; model 2, applying the two correlated factor solutions (identified in the previous EFA).

Convergent validity (Chiorri, 2023) was evaluated by the Pearson's r coefficient of correlation between the factors of the RLSES and the Perceived Scholastic Self-Efficacy Scale (Pastorelli & Picconi, 2001).

Furthermore, to evaluate the criterion validity (Chiorri, 2023), a multivariate analysis of variance (MANOVA) was performed to assess the potential mean differences in the RLSES scores, regarding the factor "level of hours spent in the ER project" (under 25 h or over 25 h, identified by a median split procedure).

The statistical analyses were carried out by the software JASP (release 0.18.1) (AA.VV, 2024).

5. Results

5.1. Study 1

The general data regarding the protocol were examined to assess the normality of distributions; we considered the values of skewness (ranging from −0.461 to +0.136) and kurtosis (ranging from −1.087 to +0.336) for all the items (detailed descriptive statistics for each item and coefficients of polychoric correlations were reported in Appendix B).

Then we applied in subsample 1 the EFA (the Minimum Residual Method of extraction) with oblique promax rotation. We consider the results of the Kaiser-Meyer-Olkin test (KMO = 0.921) (Kaiser, 1970) and the Barlett test (Chi Squared = 2114.933; df = 120; $p < 0.001$) (Bartlett, 1954), confirming the suitability of EFA (Beaujean, 2011).

To define the number of factors to retain, we observed the graphical criterion based on the scree-plot and the results of the parallel analysis (Fig. 1) (Hayton et al., 2004). Both procedures highlighted a factorial structure of the RLSES characterized by two factors in the Italian context. The first factor showed an eigenvalue of 7.296 (proportion of variance explained in the rotated solution = 0.327); the second factor showed an eigenvalue of 1.595 (proportion of variance explained in the rotated solution = 0.174). See Table 2.

The factor loadings are shown in Table 3. In the Italian version of the RLSES, the factor 1 (F1) included 12 items; specifically, we found that our students perceived as a first factor the dimensions that comprised Application, Collaboration, Comprehension, and Analysis, originally identified as distinct factors by the authors of the RLSES. This first factor refers to students' confidence regarding the application of their robotics knowledge to solve problems, about working together with peers while learning robotics in schoolrooms, and the understanding of theoretical knowledge while learning robotics, concerning the analysis of problems relating to robotics while learning robotics. The second factor (F2) included the four items referring to the Practice dimension, as in the original version of the RLSES (i.e., rating students' confidence in preparing a practical robotics task). Overall, both factors showed a good Cronbach's index of reliability (F1 = 0.910; F2 = 0.812).

5.2. Study 2

In the second study, a CFA with ULS (Blunch, 2012) was carried out on the second subsample of students. We examined the data fit concerning the one-factor solution (model 1) and the two correlated factors solution highlighted in the EFA (model 2) (see Table 4).

To appraise the fit of these models, we evaluated the following indices. First, the ratio of chi-squared and its degrees of freedom is determined acceptable if it is lower than 2 (Schermelleh-Engel et al., 2003; Wheaton et al., 1977). Also, the comparative fit index (CFI) was considered, for which a value above 0.90 is considered adequate (Byrne, 2001). The Bentler-Bonett normed fit index (NFI) had to register values over 0.95 to imply a good fit. The indices of root mean square error of approximation (RMSEA) and of the standardized root mean square residual (SRMR) had to register values less than 0.08 to define a satisfactory fit (Hu & Bentler, 1999), with generally lower values indicating an improved fit. The Tucker-Lewis Index (TLI) was recommended to be

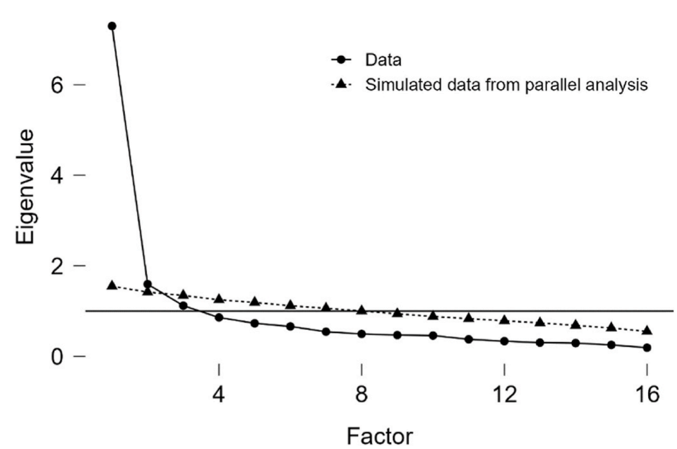

Fig. 1. Scree plot and Simulated data in parallel analysis.

Table 2
EFA factor characteristics.

	Unrotated solution				Rotated solution		
	Eigenvalues	SumSq. Loadings	Proportion var.	Cumulative	SumSq. Loadings	Proportion var.	Cumulative
Factor 1	7.296	6.816	0.426	0.426	5.239	0.327	0.327
Factor 2	1.595	1.209	0.076	0.502	2.786	0.174	0.502

Table 3
EFA factor loadings – oblique promax rotation.

		Factor 1 Application, Collaboration, Comprehension, Analysis	Factor 2 Practice
PR1 I can assemble a robot step by step.	**it1_pr1**		0.830
PR2 I know how to use the tools of making a robot.	**it2_pr2**		1.013
PR3 I can build up a circuit for a robot.	**it3_pr3**		0.390
PR4 I can make a robot.	**it4_pr4**		0.809
AP1 I can propose the ideas of using robots to solve problems.	**it5_ap1**	0.675	
AP2 I can apply robotics knowledge in my daily life.	**it6_ap2**	0.756	
AP3 I can make use of a robot to solve a problem.	**it7_ap3**	0.687	
CL1 I can discuss easily with peers how to make robots.	**it8_cl1**	0.421	
CL2 I can present my ideas clearly in a robotics classroom.	**it9_cl2**	0.770	
CL3 I can express my opinions freely in a robotics classroom.	**it10_cl3**	0.714	
CP1 I am clear about the learning concepts of robotics.	**it11_cp1**	0.576	
CP2 I can answer teachers' questions in a robotics classroom.	**it12_cp2**	0.701	
CP3 I can link robotics concepts with other learning subjects.	**it13_cp3**	0.692	
AN1 I can evaluate several robotic solutions for solving a problem.	**it14_an1**	0.598	
AN2 I can demonstrate an idea by making a robot.	**it15_an2**	0.500	
AN3 I can think of a robotics problem from different angles.	**it16_an3**	0.679	
	Cronbach's Alpha	0.910	0.812

0.96 or higher (Hu & Bentler, 1999). Finally, the expected cross-validation index (ECVI) was used for evaluating how well a model that fit to the calibration sample would perform in analogous validation samples (Kaplan, 2000). For predicting future sample covariance (Browne & Cudeck, 1992), smaller values are required than in an ECVI comparison model. Recently, Xia and Yang (2019) highlighted that during CFA, using the method of estimation of the ULS, one might observe larger CFI and TLI values and minor RMSEA values compared to the maximum likelihood (ML) method of estimation for ordinal data. For this reason, the classical thresholds identified in the literature for the application of CFA with ML (Hu & Bentler, 1999; Schermelleh-Engel et al., 2003) should be employed with caution. In our work, the evaluation of the fit indices was applied consistently with this suggestion, carefully evaluating the other evidence that corroborated the goodness of the factorial solution in the Italian context (Xia & Yang, 2019).

The CFA concerning model 2 (with two correlated factors) showed better-fit indices (Table 4), confirming the factorial structure of the RLSES highlighted by the EFA application in Study 1. The factor loadings for model 2 were all statistically significant; they are displayed in Table 5.

In the next stage of the research, for the total sample, linear correlations (Pearson's r) (Table 6) were calculated between the variables assessing age, the mean score on the RLSES for F1, and RLSES for F2, and the total score for the Perceived Scholastic Self-Efficacy Scale. We discovered that age had a significant positive correlation with RLSES F1 ($r = 0.227$, $p < 0.001$) and RLSES F2 ($r = 0.306$, $p < 0.001$); the Perceived Scholastic Self-Efficacy Scale showed a positive significant correlation with F1 ($r = 0.386$, $p < 0.001$) and F2 ($r = 0.261$, $p < 0.001$); and the two factors of the RLSES instrument showed a significant positive correlation ($r = 0.580$, $p < 0.001$). These data confirm the convergent validity of the RLSES in the Italian context (Chiorri, 2023).

To evaluate the scale's criterion-oriented validity, a MANOVA was carried out to assess the possible mean differences in the RLSES scores regarding the between-factor "level of hours spent in the ER project" (low number – under 25 h vs. high number – over 25 h, identified with the median split procedure; Tabachnick & Fidell, 2007).

The MANOVA revealed a multivariate effect of the "level of time spent in the project" (Wilk's lambda $_{(2;\ 350)} = 0.856$; $p < 0.001$; partial eta squared = 0.144).

At the univariate level, the effect of the variable "level of time spent in the project" was significant for F1 ($F_{(1;351)} = 16.724$; $p < 0.001$; partial eta squared = 0.093), and for F2 ($F_{(1;351)} = 52.375$; $p < 0.001$; partial eta squared = 0.130). Specifically, the students that attended an ER project characterized by a great number of hours (higher than 25) obtained higher scores per F1 than per F2. For F1, a low number of hours in the ER project registered mean = 3.21, SD = 0.71, versus F1 for a high number of hours in the ER project, registering mean = 3.65, SD = 0.63.

Table 4
Study 2 – CFA for model 1 and model 2.

Model	df	Chi Squared	Chi Squared/df	RMSEA	RMSEA [90 % CI]	SRMR	CFI	NFI	TLI	ECVI
Model 1 – One factor	104	256.879	2.469	0.091	[0.077–0.106]	0.082	0.972	0.953	0.967	1.823
Model 2 – Two factors	103	125.866	1.222	0.036	[0.000–0.055]	0.060	0.966	0.977	0.995	1.090

Note: df = degrees of freedom; RMSEA (90 % CI) = Root Mean Square Error of Approximation with confidence interval; SRMR = standardized root mean square residual; CFI = comparative fit index; NFI = Bentler-Bonett Normed Fit Index; TLI = Tucker-Lewis Index; ECVI = Expected cross validation index.

Table 5
CFA model 2 – factor loadings.

						95 % Confidence Interval	
Factor	Indicator		Estimate	Std. Error	z-value	Lower	Upper
Factor 1	**it5_ap1**	**I can propose the ideas of using robots to solve problems.**	0.613	0.085	7.223***	0.447	0.779
	it6_ap2	**I can apply robotics knowledge in my daily life.**	0.723	0.072	10.047***	0.582	0.865
	it7_ap3	**I can make use of a robot to solve a problem.**	0.738	0.074	9.968***	0.593	0.883
	it8_cl1	**I can discuss easily with peers how to make robots.**	0.710	0.078	9.091***	0.557	0.864
	it9_cl2	**I can present my ideas clearly in a robotics classroom.**	0.764	0.071	10.815***	0.626	0.903
	it10_cl3	**I can express my opinions freely in a robotics classroom.**	0.617	0.086	7.169***	0.448	0.786
	it11_cp1	**I am clear about the learning concepts of robotics.**	0.616	0.075	8.259***	0.470	0.762
	it12_cp2	**I can answer teachers' questions in a robotics classroom.**	0.790	0.065	12.143***	0.662	0.917
	it13_cp3	**I can link robotics concepts with other learning subjects.**	0.830	0.061	13.504***	0.710	0.951
	it14_an1	**I can evaluate several robotic solutions for solving a problem.**	0.718	0.071	10.116***	0.579	0.857
	it15_an2	**I can demonstrate an idea by making a robot.**	0.781	0.077	10.181***	0.631	0.932
	it16_an3	**I can think of a robotics problem from different angles.**	0.795	0.063	12.606***	0.671	0.918
Factor 2	**it1_pr1**	**I can assemble a robot step by step.**	0.808	0.091	8.910***	0.630	0.986
	it2_pr2	**I know how to use the tools of making a robot.**	0.969	0.065	14.929***	0.842	1.097
	it3_pr3	**I can build up a circuit for a robot.**	0.666	0.099	6.713***	0.472	0.861
	it4_pr4	**I can make a robot.**	1.013	0.066	15.401***	0.884	1.142

Note: *** p-value <0.001.

Table 6
Pearson's r *Correlations Between Assessed Scales and Age.*

Variable		Age		Perceived Scholastic Self-Efficacy Scale		RLSES F1 Application, Collaboration, Comprehension, Analysis	
Perceived Scholastic Self-Efficacy Scale	r	0.091		–			
	p-value	0.089		–			
RLSES F1 Application, Collaboration, Comprehension, Analysis	r	0.227	***	0.386	***	–	
	p-value	<0.001		<0.001		–	
RLSES F2 Practice	r	0.306	***	0.261	***	0.580	***
	p-value	<0.001		<0.001		<0.001	

Note: *p < 0.05, **p < 0.01, ***p < 0.001.

For F2, a low number of hours in the ER project revealed mean = 2.78; SD = 0.89, versus F2, a high number of hours in the ER project, having mean = 3.45, SD = 0.83 (Fig. 2). Assuming that longer-lasting ER projects support the development of greater self-efficacy in the ER discipline, these results highlight how scores on the RLSES can be valuable in highlighting the differences in the levels of ER self-efficacy of participants who experience projects of different lengths.

6. Discussion and conclusion

The aim of this research was to validate an Italian version of the RLSES, an instrument originally developed and validated in Taiwan (Tsai et al., 2021). The factorial analyses (exploratory and confirmatory), although revealing high reliability coefficients demonstrating the high internal consistency of the instrument, highlighted (differently from the original version of the RLSES) only two factors in relation to Italian students. The first factor (F1) included all the aspects pertaining to the cognitive and affective domains that make up self-efficacy in ER activities. The second factor (F2) pertained to a student's self-efficacy in the practical component of robotics linked to the psycho-motor domain.

Regarding F1, the traceable aspects were Application, Collaboration, Comprehension, and Analysis of robotics activities. These aspects in our EFA carried out on the original instrument (Tsai et al., 2021) were identified as separate factors. Despite this, the instrument in Italian worked with a total of two factors and allowed for the assessment of levels of self-efficacy in ER learning of students in the K–12 range. Thus, we found evidence of a difference in the number of dimensions that emerged in the validation carried out on the Italian sample. In the present study, items from 5 to 16 - originally divided into four subscales (Comprehension/Understanding, Analysis, Application, and Collaboration) in the Taiwanese context - were instead grouped under a single factor (F1). This difference might be related to the diverse educational environments in which the scale was administered. In Taiwan, the original study was conducted within a broader research project that

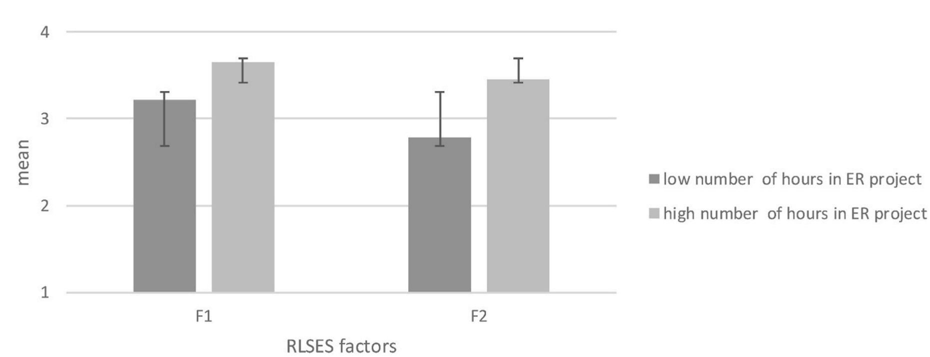

Fig. 2. Mean Scores on the RLSES F1 and RLSES F2, Regarding the Low/High Number of Hours Spent in the ER Project at School (low number – under 25 h vs. high number – over 25 h).

included targeted teacher training, based on Bloom's taxonomy; in this case, the differences between these dimensions were likely emphasized through structured instructional design. In contrast, in the Italian context, robotics activities were implemented independently by schools, with varied teaching approaches, without a unified instructional framework. This variability might have led Italian students to perceive the skills involved in Comprehension, Application, Analysis, and Collaboration as integrated and overlapping, part of an overall unidimensional representation of robotics learning self-efficacy.

In the context of ER courses with teachers, it has emerged that learning ER requires not only practical skills but also conceptual notions and transversal skills useful for shared knowledge construction (Chalmers, 2018; Toh et al., 2016; Tsai et al., 2021).

The data collected in the present research were indeed the result of a widespread administration throughout Italy, in school institutions that had independently trained their teachers in the learning of ER and that use, in teaching actions related to robotics, different methodologies and strategies. However, this led us to believe that the tool might be implemented in different learning contexts, and that it might be valid for the assessment of ER activities regardless of the design applied.

The development of robotics activities in formal educational settings is being promoted at various levels. However, in Italian schools, there is still a lack of common direction and coordination for the implementation of such experiences. In this context, the availability of an assessment tool like the RLSES becomes particularly relevant. It responds to concrete educational needs by offering a valid and sustainable instrument. Moreover, it is not tied to a single methodological approach, making it adaptable to various instructional strategies for learning robotics.

The RLSES can now be considered valid and reliable and perhaps qualified as a valuable tool for designing, implementing, and conducting research on school-based ER teaching in Italy. At the same time, the scale could be applied as an important assessment tool for students engaged in ER experiences. Indeed, the instrument, being capable of assessing students' levels of self-efficacy in learning robotics, might also become a useful support to teachers and educators if included as part of instructional planning in an ex-ante and ex post robotics activity design. In this way, teachers would have an opportunity, in the first place, to assess their students' self-efficacy in learning robotics prior to an ER course; to use the information gathered; and to be able to adopt more contextually targeted teaching approaches. Furthermore, teachers might use these data to prepare the materials and resources useful for learning purposes, and, in the second place, to ascertain, through objective student assessment, the construct in question, in relation to the implemented instructional design. This study is highly aligned with international ER education research, while also contributing uniquely by validating a psychometrically sound tool in a European context. It reinforces global findings about the relationship between ER and self-efficacy (Jäggle et al., 2020; Tsai et al., 2021; Yanış & Yürük, 2020), while challenging universal assumptions about scale dimensionality (Tsai et al., 2021). Furthermore, it encourages more cross-national validation and contextual flexibility in ER tool development—critical for advancing equitable and effective robotics education worldwide (Jäggle et al., 2020; Yanış & Yürük, 2020). Jäggle et al. (2021) highlight the importance of robust conceptual and methodological frameworks for evaluating robotics activities across educational contexts, with particular attention to key variables such as motivation, the role of tutors as models, and self-efficacy in STEM engagement. By administering the RLSES, teachers will be able to collect scores prior to ER activities and use them as a solid basis for measuring students' improvements on the implemented program mirrored in their students' self-efficacy in learning robotics (cf. Tsai et al., 2021).

Regarding the relationship between the identified factors and the other variables, it is evident that the number of ER workshop hours was related to significant differences between the factor averages. In fact, it was interesting to note that both the F1 and F2 factors showed higher scores in relation to the students who participated in projects characterized by a total amount of hours greater than 25. This suggests that implementing robotics projects in school for less than 25 h would not seem to allow students enough time to show high levels of self-efficacy in relation to ER.

In conclusion, Italian teachers' interest in ER is increasing, and teachers need reliable assessment tools they can rely on to monitor students' sense of self-efficacy, which is essential for learning, motivation and school performance. The RLSES-IT questionnaire answers, therefore, the need to have a validated and reliable tool in Italian that allows such teachers and educators to implement ER activities in their teaching, being able to assess their students' progress in a "pre- and post-design" framework and also being able to grasp the elements of effectiveness circumscribed to individual curricular plans that see the introduction of a robot in teaching-learning processes. It is also likely to be well aligned with the priorities expressed in the Italian Action Plan for the Digital School (2021–2027), as it is a valuable tool in effectively supporting the study of digital technologies in learning.

7. Limitations and future research

In terms of the weaknesses of this work, the sampling was nationwide but not probabilistic; in fact, participation was on a voluntary basis, linked to the involvement of educational institutions of different school orders. This may also represent a strength of the research, however, because it allowed the factors investigated and evaluated by all students interested and involved in multiple school-based ER projects with different learning objectives and programs. It is also necessary to mention that this instrument was based on students' self-assessments, so the results were closely linked to their personal perceptions and individual self-assessment capacities.

This research had several strengths, as well. First, the RLSES could be useful for teachers interested in assessing students' sense of self-efficacy regarding robotics. In the Italian landscape, since a validated instrument with careful verification of psychometric properties that measures explicit constructs had not been found yet, we believe the RLSES can adequately be used to investigate the above dimensions. Its use is also predicted to both help teachers in the evaluation of their robotics training programs and enable them to identify the most effective teaching strategies and the most engaging content for their students. In this sense, too, the work of instructional design is improved. Moreover, assessing students' self-efficacy can serve as an additional tool for teachers, helping them to create more balanced group dynamics, foster collaboration, support differentiated instruction, and promote an inclusive and motivating learning environment.

Furthermore, we should reflect about the fact that, while the linear correlations reported between the Perceived Scholastic Self-Efficacy Scale and the two RLSES factors (F1 and F2) are statistically significant, we acknowledge that their magnitude is relatively modest. One possible explanation of this magnitude is that the relationships between perceived self-efficacy and RLSES factors may not be strictly linear, thus not fully captured by Pearson's correlation coefficient. Moreover, self-efficacy is a multifaceted psychological construct that might act through multivariate relationships, in interaction with other variables (e.g., motivation, learning environment, socio-emotional skills); for this reason, a single linear correlation coefficient might underestimate the contribution of self-efficacy in a multifactorial context.

Finally, an evolution of the present research might consider implementing and analysing or comparing data depending on variables such as school order, type of ER program, or technology resources used. Additional future research might involve a cross-cultural validation of the instrument in the Swiss context, where ER programs are prevalent (Babazadeh & Negrini, 2022).

CRediT authorship contribution statement

Mirian Agus: Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Data curation, Conceptualization. **Arianna Marras:** Writing – review & editing, Writing – original draft, Validation, Software, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Lucio Negrini:** Writing – review & editing, Writing – original draft, Supervision, Software, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

Declaration of the use of AI

No AI tools were used to create this article.

Data availability statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Ethics statement

This study was conducted in accordance with the ethical standards outlined in the Declaration of Helsinki and was approved by the Ethical Committee in the University of Cagliari – Italy (approval number 0276446). Given that the study involved minors, additional ethical considerations were implemented to safeguard participants' well-being.

Written informed consent was obtained from the legal guardians of all minor participants, and assent was also obtained from the minors themselves in a manner appropriate to their age and understanding. Participation was voluntary, and both minors and their guardians were informed that participation could be withdrawn at any point without any negative consequences.

All collected data were anonymized to ensure the privacy and confidentiality of the participants. No identifying information was retained that could link responses back to individual participants. All procedures performed in this study adhered to the ethical standards of the institutional and/or national research committees overseeing research involving human participants, particularly minors.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ssaho.2025.101646.

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