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Towards a Collaborative Society Through Creative Learning

IFIP World Conference
on Computers in Education, WCCE 2022
Hiroshima, Japan, August 20–24, 2022
Revised Selected Papers

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Preface

Every four years, Technical Committee 3 (Education) of the International Federation for Information Processing (IFIP) has presented a major international conference: the World Conference on Computers in Education (WCCE). WCCE 2022 was held at the International Conference Center in Hiroshima, Japan. WCCE was originally due to take place in 2021 but the conference was postponed by a year due to the COVID pandemic. The conference was hosted from August 20–24, 2022 and for the first time in IFIP TC3 history was organized in a hybrid format, which also allowed participation via the Internet. The decision for a hybrid format was mainly caused by the worldwide impact of the COVID pandemic on international travel and conference participation.

WCCE was established as the main event of IFIP TC3 and a central place to share current interests in research and practice in learning and technology. WCCE creates a unique exchange place for educational excellence from all over the world, in a multidisciplinary and inter-professional spirit.

This book contains revised selected papers from the IFIP World Conference on Computers in Education (WCCE 2022), organized by Technical Committee 3: Education (TC3) and its working groups in collaboration with the Information Processing Society of Japan (IPSJ). WCCE 2022 provided a forum for new research results, practical experiences, developments, ideas, and national perspectives related to the conference focus and the themes listed below for all levels of education (preschool, primary, secondary, higher, vocational, and lifelong learning), including the professional development of educators (teachers, trainers, and academic and support staff at other educational institutions) and related questions on educational management.

The special focus of the WCCE 2022 conference was *Towards a Collaborative Society Through Creative Learning*, which has also been selected as the title of this book. As the world is increasingly interconnected and complex, the need for more critical and creative thinkers as well as for people to be able to fruitfully collaborate with others is increasing. Creative strategies must be implemented in education so that citizens in general, and students at all levels in particular, are better prepared to create new and meaningful forms of ideas, take risks, and be flexible and cooperative.

Submissions to the conference were invited to address one or more of the following *four key themes*:

- Digital education in schools, universities, and other educational institutions.
- National policies and plans for digital competence.
- Learning with digital technologies.
- Learning about digital technologies and computing.

Altogether, 174 submissions of full and short papers, symposia, posters, demonstrations, workshops, panel sessions, and national sessions were received and reviewed by reviewers in a double-blind peer-review process. Among these submissions were 91 full papers (12 pages in length) and 40 short papers (six pages in length), totalling 131.

Each of these academic papers was initially reviewed by three reviewers. Five further academic papers resulting from the Symposia at the conference were submitted after the conference had taken place, which were also reviewed by three reviewers each. Altogether, there was a total of 136 papers (96 full papers, 40 short papers). Sixty-one papers (54 full papers and 7 short papers) were accepted for publication in the volume at hand. The overall acceptance rate was 44.9%. The initial reviewing period lasted for approximately 30 days and successful manuscripts that were accepted for the book were then revised again. Manuscripts that were evaluated to need major revision were subjected to a further round of reviews that lasted for a further 30 days. In the initial round of reviews, the average number of submissions assigned to a reviewer was 5.7 papers.

The revised selected papers in this book arise from contributions from (in alphabetical order) Australia, China, Estonia, France, Germany, Greece, Indonesia, Ireland, Israel, Italy, Japan, Kenya, Malaysia, Morocco, New Zealand, Norway, Portugal, Serbia, Slovakia, South Africa, South Korea, Switzerland, Taiwan, the United Kingdom, and the United States of America, which reflects the conference's success in bringing together and networking experts from many countries worldwide.

This book selects a range of research papers that focus on the ways that digital applications and computing education have, are, and will help to develop a collaborative society. It includes papers that concern new and developing uses of digital applications and computing in professional practice, and long-term implications and effects on society and creativity. This book brings together papers that illustrate and detail these forms of digital and computing education, across a wide range of countries, in different contexts. The text focuses on the need for more critical and creative thinkers as well as for people able to fruitfully collaborate with others as the world becomes more and more interconnected and complex. Creative strategies must be implemented in education so that citizens in general, and students at all levels in particular, are better prepared to create new and meaningful forms of ideas, take risks, and be flexible and cooperative.

The book is organized into the following sections:

- Digital education and computing in schools
  - Digital education in schools
  - Computing in schools
- Digital education and computing in higher education
  - Digital education in higher education
  - Computing in higher education
- National policies and plans for digital competence

Digital Education

Digital education has revolutionized the way schools, universities, and other educational institutions approach teaching and learning. In innovative institutions, it has provided a platform for nurturing creativity by encouraging students to explore new ideas, engage in collaborative projects, and think critically. Integrating technologies into teaching practices has enabled educators to develop effective and creative pedagogies, making learning more engaging and interactive. Digital tools have also facilitated assessment, evaluation, and certification processes, ensuring a comprehensive and efficient approach to tracking students' progress. Moreover, educational institutions have focused on empowering educators through training and professional development programs, equipping them with the necessary skills to leverage digital resources effectively.

Recent phenomena such as virtual education and haptic technologies have opened up new avenues for learning and engagement. These technologies have not only enhanced the accessibility of education but have also provided opportunities for students to actively participate in their learning processes. With the emergence of digital tools supporting collaboration and practice, students and teachers have assumed new roles, transforming traditional classroom dynamics. Students now have the ability to collaborate globally, engage in project-based learning, and develop critical thinking skills through online discussions and collaborative platforms. Furthermore, the use of digital technologies has extended beyond formal learning environments, connecting informal learning situations with formal contexts. This integration promotes lifelong learning, as individuals can access educational resources, tutorials, and interactive platforms outside of the traditional classroom setting. Learning with digital technologies has undoubtedly enriched the educational experience, fostering a dynamic and interactive approach that prepares students for a rapidly evolving digital world.

Learning about computing has become increasingly important in today's digital age. Exploring computational thinking lays the foundation for understanding the logic and problem-solving skills necessary for effective engagement with digital technologies. Computing and computer science education provide students with the knowledge and skills to navigate the ever-evolving digital landscape. Programming languages tailored for education offer an accessible entry point for students to develop coding proficiency and computational skills. By embracing learning about digital technologies and computing, students gain the necessary skills and knowledge to thrive in the digital era and contribute meaningfully to the advancement of technology.

National Policies and Plans for Digital Competence

National policies and plans for digital competence play a pivotal role in shaping the educational landscape. Through the analysis of national cases and comparisons of different plans and policies in various countries, it becomes evident that a strategic approach is essential for fostering digital competence among students. These policies guide the development of curricula that integrate digital skills into the core subjects, ensuring that students are equipped with the necessary knowledge and capabilities to thrive in the digital era. By establishing clear guidelines and goals, national policies provide a framework for curriculum development that aligns with the evolving needs of society. Furthermore, they encourage the inclusion of digital literacy, coding, and computational thinking across disciplines, enabling students to develop a comprehensive understanding of digital technologies.

We would like to thank everyone who was involved in the organization of the WCCE 2022 conference – as a member of either the program committee or the local organizing committee, as a reviewer, or in any other role for the substantial work they did to make this conference a success! Regarding the book-editing process, we would also like to thank the working group "Informatische Bildung NRW" of the German Informatics Society (GI) for providing their ShareLaTeX server for collaborative editing of LaTeX papers.

We hope that the choice of papers in this volume will be of interest to you and further inspire your own work. 'Towards a collaborative society through creative learning' is a development that is of central importance to all countries and communities; we thank the authors of the included papers for offering important, new, and contemporary perspectives that lead the discussion in this field.

July 2023

Therese Keane
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Assessing Engagement of Students with Intellectual Disabilities in Educational Robotics Activities

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Abstract. Engagement is a multi-componential construct, difficult to measure in its general form as in the typical development but even more in the atypical development. Currently, there are no instruments in the literature to measure engagement in its different dimensions (behavioural, affective, social and cognitive) for students with intellectual disabilities involved in creative robotics activities. With this aim, we tried to apply a survey system based on the triangulation of three ad hoc tools: an observation grid, analysis of verbal productions and a questionnaire. This triple system of application allowed us to understand whether the creative robotics activity proposed to children with intellectual disabilities aroused their interest and involvement, and to what extent.

Keywords: Engagement · Student with intellectual disability · Educational Robotics

1 Introduction

Following the EU educational policies, the last Education Reform in Italy (2016) introduced computational thinking at all school levels. Regrettably, in the Italian school reality, students with intellectual disabilities (ID) appear to be excluded from programming activities with educational robotics (ER) [1]. The research literature confirmed the same gap: there are very few publications on educational ER programming activities with students with ID [2]; most research is focused on humanoid robotics, the role of assistive devices or the effectiveness of computer-assisted instruction. The range of publications narrows dramatically when examining the age of students: the few existing studies focus mainly on children between 6 and 12, while adolescents aged 15 to 20, in high school, appear decidedly under-represented [2]. Therefore, this exploratory study aimed to measure the engagement of 8 high school students with ID, aged between 16 and 22, in ER programming activities (with Arduino as base), in a school in the North-East of Italy. In this work, considering the target students, we considered very simple activities of programming and coding: for example, students lifting flashcards (paper or digital) to make the robot perform the specific action displayed in the flashcards.

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Engagement is considered a key construct to identify the educational potential of ER activities, at behavioral, cognitive, affective, and social levels. Although there is a conspicuous amount of research on this construct in the educational field for typical development, the study of engagement for atypical development is still limited to the use of robotics in therapeutic and clinical settings (particularly with the use of humanoid robotics). Thus, there is a gap in the literature on the educational dimension of engagement of ER programming activities for students with ID [2]. To measure the engagement of these students, we constructed and applied three ad hoc research instruments: an observation instrument, a verbal interaction analysis instrument and a questionnaire. In the next paragraphs, the definition and measurement of engagement will be analyzed, the tools of our proposal will be described, and finally the tools will be applied to a case study of 8 students with ID engaged in basic robotics activities.

2 Engagement and Its Measurement

The meaning and measurement of engagement has evolved over time "to represent increasingly complex understandings of the relationships between desired outcomes of college and the amount of time and effort students invest in their studies and other educationally purposeful activities" (pp.683) [3]. Engagement is generally described as a multi-componential construct and over time several models have been constructed to define it. For example, Finn's [4] model includes two components: behavioural (participation) and affective (identification, belonging, evaluation). The same categories are considered by Skinner et al. [5] in their comparison between Engagement vs. Disaffection, both involving a behavioural and an affective aspect. Other authors add a further component, cognitive, linked to self-regulation goals and the amount of investment [6]. Gunuc & Kuzu [7] recall the importance of the social aspect, which is mutually dependent with engagement, especially in school and learning contexts.

The measurement of engagement levels is one of the most challenging issues for researchers in the field. Until the late 1990s this issue had been placed on the back burner [8]. However, over the last two decades a number of scholars have focused on the variety of data collection techniques most suitable for measuring engagement. The most common are self-report measures. Among the earliest are Jacques' [9] 13-item interview containing questions about attention, perceived time, motivation, needs, control, attitudes and general engagement and Webster and Ho's [10] seven-item questionnaire with questions about attention, challenge, intrinsic interest, and variety. They are followed by more recent instruments such as the User Engagement Scale by O'Brien & Toms [11], the Motivation and Engagement Scale by Liem & Martin [12] and the UTAUT model by Heerink et al. [13].

Despite the increase in research on this subject, there seem to be considerable difficulties in measuring cognitive and psychological engagement. Frequently, the same questions can be used to represent different subtypes of engagement, while the subtypes are often examined separately, precluding further levels of comparison [6].

Some researchers have used performance indicators, not as direct measures of engagement, but as its correlates. For example, Konradt and Sultz [14] used pre- and post-activity measures to examine changes in users' affective and cognitive states during interaction with an educational application. However, even metrics such as interaction analysis, number of eye fixations, heart rate, etc., have limitations: they explain what is happening during a user's interaction with a given activity, but do not address the cognitive or emotional state of users, which are crucial for engagement [10].

There is also the problem of generalizability of the results: often a tool is valid for the precise domain or activity it was constructed for, but these results are not applicable to other domains. Moreover, the elements contained in each of these tools represent a small part of the engagement attributes indicated so far.

Champion [15] hypothesized that multiple measures (self-report, participant observation, biometrics) are needed to study engagement, but did not offer any empirical results or describe how these measures could be triangulated to say anything meaningful about engagement. Therefore, for our purposes, we decided to build ad hoc tools, to measure engagement of student with cognitive disability, which will be outlined in the following sections.

3 Tools Developed to Measure Engagement

3.1 Observation Grid

The observation grid included the analysis of non-verbal expressive behaviour. We were inspired by the work of Mehrabian [16], making appropriate modifications for our activity, as we will explain below. The behaviours were divided into three categories: Posture and stance, and Movements and Facial expressions. The first category includes: Touch, Distance, Stretching, Eye contact, Body orientation. Since most of the robotics activities were carried out in a sitting position, only touch and eye contact were analysed.

In the second category are: Trunk movements, Swinging, Nodding, Gesturing, Self-manipulation, Foot and leg movements. For the same issue of seated positioning, some categories were excluded; we selected nodding, gesturing and self-manipulations or stimming (i.e., repeatedly touching a part of one's own body, finger-flicking and so on). In relation to trunk and arm movements, the asymmetrical position of the arms is interpreted as a sign of relaxation.

The third category is devoted to Facial expressions and is divided into Positive and Negative expressions. We chose to analyse the most frequent and explicit expressions: smiling and laughter as positive interactions, and yawning indicating boredom and disengagement.

The following criteria were used to compile the observation grid:

1. *Duration of eye contact* with the different objects: duration is expressed in seconds of fixations towards the interlocutor and the objects selected for each activity: robot, paper and digital flashcards with arrow, carpet, interactive whiteboard.
2. *Number of eye contacts* with different objects: the number of direct fixations of eye contact towards the interlocutor and the objects selected for each task are counted: robot, paper and digital flashcards with arrow, carpet, interactive whiteboard (IWB).
3. *Number and duration of facial expressions*: smiling, laughing, yawning, etc. are counted.

4. *Number and duration of body movements*: gesturing, nodding, self-manipulations, standing up and sitting, relaxation, stimming are counted.
5. *Number and duration of physical distance from objects*: spontaneous touching, touching on command, hesitation to respond are counted.

In relation to the above classifications, it can be noted that eye contact refers to the behavioural aspect of engagement, as it involves physical movement, therefore it is related to the factors Time on task [6], Focused attention [8], Persistence [12], Use [13] and Effort [5].

The *number of ocular occurrences* signals interest and attraction and is therefore related to the factors Novelty [8] and Interest [5].

Facial expressions represent the emotions felt towards the object or activity; therefore, they are related to the factors Attitude and Perceived enjoyment [13], Felt Involvement [8] and Enjoyment [5].

Body movements can be interpreted as emotional signals of nervousness or relaxation; therefore, they are related to Anxiety [13], Uncertain control [12], Self-regulation [6] and Perceived usability [8].

The *physical distance from the objects*, in particular in the meaning of *spontaneous touching*, indicates Perceived ease of use [13], Participation [6], Self-efficacy [12], Aesthetic [8], Enthusiasm and Exertion [5].

Time indicates the duration of each work phase, including some, not many, moments of relaxation and those dedicated to the actual activity. The category *Eye contact* reports a continuous event, as it indicates the duration of eye fixation and is expressed in seconds. The other categories indicate punctual events and are expressed in number of times per minute.

3.2 Verbal Expressions

Also, via video recording, it was possible to transcribe the verbal comments of the pupils. They were classified into two categories according to the extent of verbal production: *short interjections* and *complete words or sentences*. Subsequently, the spontaneity of these productions was assessed: "*Completely spontaneous", "In response to a question*" or "*Completion/repetition of portions of sentences*" produced by the interlocutor. Spontaneous productions indicate a greater involvement and state of well-being on the part of the pupil, while responses to questions and completion of sentences indicate a high degree of participation but less ease in the situation. In addition to these, the category "*Avoidance of answer*" was added to indicate the condition of discomfort and low willingness to participate [17].

3.3 The Questionnaire

The questionnaire (see Table 1) was composed of the most frequent factors mentioned in the literature. In particular, we selected questions with a direct correspondence in the classifications of the five mentioned authors. The aim was to create an instrument lean and quick to complete (19 items), with questions presented in lexically and syntactically simple formulations. The questions are posed in the affirmative form and the participants are asked to mark their agreement with the proposed statements in a 5-level Likert scale. The answers are accompanied by a verbal label (5 = Completely agree, 4 = Agree, 3 = Uncertain, 2 = Disagree, 1 = Do not agree at all) and a graphic representation (a smiley more or less smiling).

Table 1. RE engagement questionnaire for students with ID

Item	Heerink [13]	Appelton et al. [6]	Liem et al. [12]	O'Brien et al. [8]	Skinner et al. [5]
It's nice to use the robot	Attitude	Participation	Self-efficacy	Aesthetic	Enthusiasm
I like working with the robot	Perceived enjoyment	Participation	Self-efficacy	Felt involvement	Enjoyment
I like giving commands to the robot	Perceived Enjoyment	Participation	Self-efficacy	Felt Involvement	Enjoyment
I want to know more about robots	Perceived usefulness	Aspiration	Mastery orientation	Novelty	Interest
I want to continue the activity now	Intention to use	Time on task	Persistence	Endurability	Persistence
I am afraid of making mistakes*	Anxiety	Self-regulating	Anxiety	Perceived Usability	Exertion
I'm afraid of breaking the robot*	Anxiety	Self-regulating	Anxiety	Perceived Usability	Exertion
It is easy to command the robot	Perceived ease to use	Strategizing	Self-efficacy	Perceived Usability	Exertion
I'm scared of the robot*	Anxiety	Self-regulating	Anxiety	Perceived Usability	Enthusiasm
The robot is difficult to use*	Perceived ease to use	Strategizing	Uncertain control	Perceived Usability	Exertion
Papers flashcards with arrow are easy to use	Facilitating Condition	Strategizing	Self-efficacy	Perceived Usability	Effort

(*continued*)

Table 1. (*continued*)

Item	Heerink [13]	Appelton et al. [6]	Liem et al. [12]	O'Brien et al. [8]	Skinner et al. [5]
Digital flashcards with arrow are easy to use	Facilitating Condition	Strategizing	Self-efficacy	Perceived Usability	Effort
I'd spend my free time playing with robots	Intention to use	Value	Persistence	Endurability	Interest
I'm not interested in this activity with robots*	Perceived usefulness	Value	Disengagement	Felt Involvement	Interest
I got bored*	Attitude	Participation	Disengagement	Felt Involvement	Interest
It made me angry*	Attitude	Self-regulating	Disengagement	Felt Involvement	Enjoyment
I want to continue using the robot at school	Intention to use	Completion	Persistence	Endurability	Interest
I want to take the robot home	Intention to use	Completion	Persistence	Endurability	Interest
I want to use it with my schoolmate	Social influence	Participation	Valuing	Endurability	Enthusiasm

There are 13 questions concerning positive conditions (e.g., "It is easy to control the robot") and 6 questions are reported in the opposite form, marked with asterisks (*) in the table (e.g., "The robot is difficult to use"). Despite the adjustments and simplifications, several pupils were not able to read and fill in the questionnaire independently. It was therefore necessary to read the questionnaire and simplify the way of answering. The questionnaire took the form of a structured interview. The adaptations necessary show that the questionnaire is not the easiest or most reliable tool to use in ID contexts. Hence, we suggest turning it into a more interactive conversation and to accompany it with observation.

4 Case Study

4.1 The Educational Activity with Creative Robotics

The classroom activity was carried out individually by the pupils. After a brief presentation, a researcher began with a recited tale of Aesop's The Mouse and the Frog, to introduce the protagonists of the activity. Then the robot, called Rospino© [18], was presented and the pupils were asked to complete it by assembling some of its parts, in-volving them in the simplest stages of its construction. The robot represented the frog in the story and it had to replicate some of the character's actions or movements (e.g., reaching his friend the mouse, entering the pond, reaching the den while avoiding the kite, etc.), moving on a decorated carpet.

The aim was to program the robot's movements (coding), so it would reach the target object or character, through four paths of increasing difficulty. The movement could be programmed in three ways with increasing levels of abstraction: low, physically moving oneself and the robot along the path; intermediate, selecting the directional paper flashcards with arrow, representing arrows, needing to show the robot the path; and high, clicking the digital flashcards with arrows directly through the interactive whiteboard (IWB).

Not knowing the abilities of the pupils, who had very different intellectual levels and coding experiences, it was decided to start the activities at the intermediate level. If the pupil proved to be particularly good at selecting the instructions on paper, he or she went directly to programming software; if he or she had difficulties, the activity could be simplified further with manipulable materials. The total duration of the activity was about 45 min.

4.2 The Participants

Eight young students aged between 15 and 20 years, attending a high school in north-eastern Italy, participated in the case study. Among them were seven males and one female. All of them presented certified ID of various degrees, from mild to moderate. The nature of the disability was different: Down's Syndrome, Autism Spectrum Disor-der, premature birth, and other undefined aetiologies. Only children whose parents gave their permission and willingness to accompany them during extracurricular hours participated. The students were asked if they were interested in participating in the activity. They were given time to see the setting and the materials. They could stop the activity at any time according to their wishes and needs. The pupil's support teacher was present at the activities.

4.3 The Method

The entire activity was video-recorded, and the observation grid was applied retrospectively, using the ELAN coding software to note the number and duration of the behaviours observed. Some indices were transformed into percentages and number of events per minute to make them comparable despite the different duration of the overall recording.

The questionnaire was submitted at the end of the activity, reading support was provided, or the structured interview method was used. It was not possible to administer the instrument to a pupil who, due to excessive fatigue, did not show his willingness. The small number of participants made it impossible to apply inferential statistical analyses, nor to compare the responses of males and females.

5 Results

5.1 Questionnaire and Interview

The pupils declared their involvement in the ER activity, in fact the questions "Is it nice to use the robot?" and "Do I like working with the robot?" obtained the highest score (5) among all respondents, as well as their reciprocal in the negative "Did I get bored with during the activity with the robot?" and "Did this activity with the robot make me angry?" obtained the lowest score (0).

A slight difficulty in the use of the tools (e.g., paper, and digital flashcards) was perceived, as the related questions received slightly lower average scores "Do you like giving commands to the robot?" (4.86), "Is it easy to command the robot?" (4.57), "Is it difficult to use the robot?" (4.43), "Are the digital flashcards with arrows easy to use?" (4.50), but not "Are paper flashcards with arrows easy to use?" which gets full marks (5). The question is explained by the fears that emerge regarding possible mistakes, "Are you afraid of making mistakes?" (3.86) and damage, "Are you afraid of breaking the robot? (4.43).

The boys declared that they wanted to continue the activity immediately (4.29), in their free time (4.57), at school (4.86) and at home (4.43). Some more doubts arose about the possible involvement of their companions in the activity (3.86).

5.2 Observation Grid

The eye contact showed that the pupils were able to focus their attention correctly on the object of each activity: during the narration phase, they observed the interlocutor 67.27% of the time; during the presentation and assembly phase of the robot, their gaze was directed 59.14% of the time to the robot; during the coding phase with paper flashcards, attention was directed to the arrow flashcards for an average of 62.6% of the time among the four proposed exercises; the interactive whiteboard (IWB) received attention 44.72% of the time it was used; and their gaze returned to the robot 51.08% of the time it was moving on the carpet (see Table 2).

The glances directed at other objects are, however, quite relevant to the activity: during the narration phase 11.42% of the time, they directed their gaze at the paper flashcards representing the characters in the story.

During the different phases, eye contact with the interlocutor remained constant, on average 13.71% of the time, as he continued to give explanations or phrases of encouragement to the pupil.

The other object that seems to have attracted their attention, even when it was not at the centre of the activity, is the robot, at 12.63% of the time on average, which is a good sign for an educational robotics workshop.

Table 2. Eye Contact: occurrences in % per activity sections (stage)

Stage	Robot	Flashcard	Speaker	IWB
Narration	02.80	11.42	67.27	00.00
Robot	59.14	00.29	10.70	00.00
Paper Flashcard 1	16.24	58.78	09.94	00.00
Paper Flashcard 2	16.27	66.77	10.54	01.10
Paper Flashcard 3	16.83	62.48	12.54	00.00
Paper Flashcard 4	09.98	62.43	22.83	00.00
Digital Flashcard (IWB)	14.39	07.97	16.97	44.72
Movement (carpet)	51.08	00.16	12.32	00.85

The moment in which eye contact appeared less focused, i.e., the only phase in which attention was directed to the key object less than half the time, was the programming phase on the interactive whiteboard, as the pupils frequently directed their eyes to the digital flashcard and the robot to remember the sequence of commands to be entered.

As regards the occurrences, i.e., the number of glances directed at each object, the pupils shifted the direction of their gaze on average 10 times per phase. Most of the glances were directed at the interlocutor (10.63/min) alternating with the target object of the activity of the moment (see Table 3).

Table 3. Eye Contact: occurrences of the number of glances in minute

Stage	Robot	Flashcard	Speaker	IWB
Narration	01.93	01.73	06.28	00.00
Robot	03.75	00.13	10.42	00.00
Paper Flashcard 1	03.54	05.29	09.66	00.00
Paper Flashcard 2	02.74	04.87	09.71	00.68
Paper Flashcard 3	02.44	04.86	11.77	00.08
Paper Flashcard 4	02.08	04.57	19.33	00.00
Digital Flashcard (IWB)	01.61	01.35	05.92	04.14
Movement (carpet)	03.89	00.09	11.96	00.18

Concerning Facial expressions, smiling was the most frequent, occurring an average of 5 times per phase, approximately 1.4 times per minute. The phases that produced the most smiles were the narration (2.12/min) and the assembly of the robot (2.37/min). The phases that produced fewer smiles were the initial programming activities with the paper flashcards (between 1.16 and 1/min), which probably required more concentration.

Real laughter arose only during the comic moments of the narration (0.32/min), rare in the moments of work with robots (0.09/min) and the interactive whiteboard (0.10/min).

Laughter was completely absent in the phases of work with flashcards which, as already noted, required more effort.

Yawns were only produced by one boy, who left the activity prematurely, stating that he did not feel well due to irregular sleep the night before. Other expressions, including expressions of perplexity, thought and concentration or looks of agreement were produced by only three pupils, the most sociable and least shy of the group.

With regard to Movements, the most frequent was the movement of the head indicating consent, i.e., nodding (2.56/min), followed by significantly less frequent gestures indicating participation in the dialogue and attempts at explanation (1.1/min). Self-handling gestures indicating discomfort were scarce (0.73/min) and body movements to stand up or sit down when not requested were very rare (0.23/min).

Concerning Physical contact with objects, the pupils often tried to touch the objects of the activity spontaneously, on average 4.41 times per phase, or 1.4 times per minute. This occurred especially in the last phases of programming with the digital flashcards (2.5/min), a sign that they had become familiar with the activity, and during the movement of the robot (1.57/min). There were practically no Hesitations in responding (0.15/min), except the few that occurred during the programming phase with the interactive whiteboard (0.30/min), in fact it was the only phase in which it was necessary to give more precise commands on what to touch (0.85/min). The interactive whiteboard is a tool that pupils have in class and daily use. It is possible, however, that during curricular activities teachers explicitly limit contact between pupils and the interactive whiteboard for fear of damage and that this attitude has inhibited pupils from using it spontaneously.

5.3 Verbal Expressions

The pupils produced an average of 14.72 verbal comments per phase, i.e., approximately 6.27 comments per minute. Most of them were whole words or sentences (78%) and only a minority were short interjections (22%). Of these, 51% were produced spontaneously, 37.25% in response to a question and 11.43% in completion or repetition of parts of the interlocutor's sentence. As is normal, there were some boys who were more talkative than others: the maximum verbal exchange was reached by a boy who produced 11.10 comments per minute, 56% of which were whole sentences and 43% short interjections. Of these, 60% were spontaneous, 30% in response and 11% in completion. The smallest interaction was with the girl, evidently more shy, who produced 1.74 comments per minute, of which, however, 98% were words and 2% interjections, thus demonstrating a certain communicative effort. Only 27% were related to spontaneous productions, while 50% were provided in response to questions and 21% to complete sentences.

Response avoidance was almost nil. Even in the rare cases in which the verbal response was late in arriving at the interlocutor's input, it was replaced by eye contact and facial expressions.

6 Discussion

The results that emerged from observation matched the answers in the interviews.

The pupils declared a high involvement in the ER activity and in fact the direction of their gaze, directed more than half of the time to-wards the key object of the activity, confirmed this finding. Facial expressions and body posture also showed conditions of ease and well-being, while the frequency of spontaneous tactile contact with the objects demonstrated their confidence and interest. Expressions of boredom or discomfort were minimal.

The pupils expressed a slight difficulty in using the tools, particularly in the initial phases of programming with the paper flashcards: this was detected by the pupils' constant glances at the interlocutor in search of confirmation, the number of gestures to implement their explanations and the difference in the frequency of smiling expressions and tactile contact with the objects. This clumsiness often tended to diminish in the later stages, a sign that the children were now familiar with the tool. As pointed out, the most difficult device to use was the interactive whiteboard, which required more direct instructions (e.g. "to take a step forward, click on this icon with the forward arrow"). The problem turned out to be related to the fear of making mistakes, breaking something, or causing damage.

The pupils declared they wanted to continue the activity, and the behavioural feedback to this statement can be seen by counting the small number of times the participants tried to get up or sit down to move away from the activity in progress. The fact that they were focused on maintaining visual and tactile contact with objects and inter-locutors is a clear indication of their involvement. It is of course not possible to verify the truth regarding their intentions to continue the activity at other times of the day.

Eye contact, number of occurrences and facial expressions were found to be the most useful indicators: relatively easy to measure, applicable in any context and strongly predictive of the degree of interest and involvement. Particular attention should be paid to the subcategories of facial expressions. Only the more extroverted and higher cognitive level pupils indulged in more complex expressions; for the others the range of expressions was limited to selected basic expressions.

Body movements are more difficult to assess, as they are limited by the type of setting and activity performed. In the design phase of the instruments, it was decided to select only some of the categories listed by Mehrabian [16]. Distance, Stretching and Body Movements were not assessable in a sitting position, as well as Trunk Movements, Swinging and Foot and Leg Movements, which may, however, be interesting to measure in another work context. Also, the category Relaxation/Arm symmetry, although included in the measurement, proved difficult to assess in a sitting position and not very significant with respect to the real perception of well-being of the children. Motor stereotypes were only performed by the boy with autism spectrum syndrome at the end of the activity, indicating emerging fatigue.

Verbal interactions showed a high degree of participation and comfort in the workshop situation, as most of the comments were spontaneously produced and composed of whole words and/or sentences. There was almost no response avoidance. The analysis of verbal comments, however, turned out to be a partial instrument for the measurement of engagement: it is too subject to pupil's differences, linked to cognitive level and pathology. Moreover, it is extremely limited if not combined with the recording of facial expressions and gestures accompanying verbal production.

7 Limits and Conclusions

The triangulation of the instruments proved to be an indispensable method of detection. Each of the three devices proved to be useful for measuring the level of engagement but limited when taken individually.

A major limitation remains the impossibility of establishing standardised parameters that can be used as thresholds to indicate a sufficient range of attention. Eye contact maintained for more than half of the time on the object of interest is a clear sign of engagement in the activity in progress. However, this, and especially the other parameters are very sensitive to personal, setting- and activity-related variations. For example, a high percentage of spontaneously produced words and sentences is a good indicator of social engagement, but a more introverted person will tend to produce fewer verbal comments than a more sociable person, without their engagement being lower. This variability increases further in the presence of syndromes or diseases of different aetiology, as in this case.

Replicating the research in different contexts, it will be possible to refine the tools in order to make them each time more suitable to the setting (e.g., sitting or standing), to the activity (with more or fewer objects used in sequence or at the same time), as well as to different syndromes causing disability (different intellectual levels, socialisation disorders etc.).

From the data, it can be considered that the triad of tools used showed characteristics of completeness, as it covers the four components of engagement; and of ductility as it can be easily modified to make it more suitable to one's own setting; and of practicality, as it can be applied to various contexts, even by teachers.

Note: for reasons of national assessment of Italian university research, the authors must declare which sections each has written, in spite of the fact that work is entirely the result of continuous and intensive collaboration. Sections 2, 3, 4 and 7 are by F. Coin. Sections 1, 5 and 6 are by M. Banzato. Our thanks to P. Tosato, G. Riello and M. Hoffman.

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