# An Empathic Robotic Tutor for School Classrooms: Considering Expectation and Satisfaction of Children as End-Users

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**Abstract.** Before interacting with a futuristic technology such as a robot, there is a lot of space for the creation of a whole set of expectations towards that interaction. Once that interaction happens, users can be left with a hand full of satisfaction, dissatisfaction, or even a mix of both. To study the possible role of experience as a mediator between expectation and satisfaction, we developed a scale for HRI that measures expectations and satisfaction of the users. Afterwards, we conducted a study with end-users interacting with a social robot. The robot is being developed to be an empathic robotic tutor to be used in real schools, with input from primary end-users (children). Children's expectations and subsequent satisfaction after the interaction with the robotic tutor were analysed. The results can be fed back to the system developers on how well it is being designed for such a target population, and what factors regarding their expectation and satisfaction have shifted after the experience of interaction. By delivering on the children's expectations, we aim to design a robotic tutor that provides enough satisfaction to sustain an enjoyable and natural interaction in the real educational environment.

**Keywords:** Human-Robot Interaction · User-centered design · Robotic tutor · Expectation · Satisfaction

## 1 Introduction

Robotic characters are becoming widespread as useful tools in assistive [12], entertainment [17] and tutoring applications [7]. Besides, robots can be considered a mediatic type of technology as they are easily associated with science-fiction culture (*e.g.,* sci-fi novels, movies and adverts), making the expectations of people towards robot's an important aspect to consider in the process of designing and creating a robot. In fact, sci-fi culture ends up delivering information, most of the times unrealistic information, about a type of technology that is nowadays being created, bringing expectations over robots that are far from being achieved [3]. It is well known that previous expectations strongly influence


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satisfaction, so analysing initial expectations of users before interacting with a robot becomes important when concluding about their subsequent satisfaction of the experience.

The novelty of our work regards the measurement of the expectations and satisfaction levels that users have towards a robot, to serve as an input that informs the iteractive process of designing and creating a social robot. In line with this, we developed the Technology-Specific Expectation Scale (TSES) to measure users' expectations before seeing and before interacting with a robot, and the Technology-Specific Satisfaction Scale (TSSS) to measure their satisfaction after the experience of interaction. Both scales constitute a novel metric in HRI, leading to a new complementary way of approaching the iteractive process of designing a social robot. We base our research in the study of the expectations that children had towards the possibility of interacting with a robotic tutor and compare such expectations with the satisfaction level after the interaction. The robot used throughout this paper is being developed in the FP7 EU EMOTE project[1] to be an autonomous empathic robotic tutor aimed to teach topics about sustainable development to children in schools. The study followed a methodology that merges an autonomous robot with a Wizard-of-Oz (WoZ) [19]. The motivation of this research underlies the measurement of children's satisfaction towards a robotic tutor in an educational environment to serve as an input to inform further design developments of the same tutor. The evaluation of expectations/satisfaction involves factors related with education and learning, such as the perceived capabilities of a tutor. We aim to understand which features of the robotic tutor meet the expectations of children, and which do not. Thereafter, we will detain key-information about which still need refinement and which are performing well. Moreover, most people (including the children that participated in this study) never had any previous experience with social robots, so we anticipated that people detain preconceived ideas about this type of technology, built upon sci-fi culture. Due to this, expectations and satisfaction regarding the fictional views of the robot were also assessed and taken into account, enabling a contextualised interpretation of results.

Thus, in this paper we present the developed scales for measuring expectation and satisfaction in HRI; the results of the administration of the TSES and TSSS to children towards an empathic robotic tutor for education; and guidelines that inform the design based on this novel metric for HRI. In line with this, we formulate the following study hypothesis:

**H1** The expectations that children have regarding the experience of interacting with a robotic tutor will be high as robots are part of strong sci-fi culture that children are familiar with.

**H2** By building a robotic tutor inspired in real teacher-student interactions, children will detain high satisfaction levels after the experience of interaction.

[1] EMOTE project: http://www.emote-project.eu/

## 2 Related Work

Expectation and satisfaction are concepts that influence the way we evaluate experiences. In this Section, we will detail about such concepts and relate them with HRI applied to education.

### 2.1 Expectation and Satisfaction in HRI: Definition of Concepts

In the field of HRI, Bartneck and Forlizzi (2004), have defined a *social robot* as *"an autonomous or semi-autonomous robot that interacts and communicates with humans by following the behavioral norms expected by the people with whom the robot is intended to interact"* [4]. On the creation of robots that are intended to interact with people in daily life, Wistort (2010), has also brought up the fact that *"the form of a robotic character greatly determines the affordances it provides, influencing the perceived function of the character"*. This means that people immediately create expectations about a robotic character once they see it, just based on its appearance. The majority of robots' appearance is presented to people through sci-fi culture, showing them robots that are far different from the real developed robots, thus stimulating peoples' preconceived ideas (expectations) about the functions of robots [21].

Moreover, the Expectation-Confirmation Theory (ECT) is widely used in the consumer-behaviour literature to understand consumers' satisfaction after purchasing a product. According to this theoretical framework, consumers first form an initial expectation of a product, and during a period of initial consumption (experience of the product), they assess its performance to determine if their expectations are confirmed. Finally, they form a satisfaction towards the product based on their confirmation level and expectation on which that confirmation is based [15]. In line with this, ECT appears as a framework that can inspire metrics for the design and development of future technology, such as a robotic tutor for futuristic classrooms. So, *expectations* provide a baseline or reference level for users to form evaluative judgements about the experience with a product in which lower expectations usually influence satisfaction positively, if the previous expectations are confirmed by experience [5]. Nonetheless, when evaluating an innovative technology such as a robot, it is important to consider that user's expectations can be coloured by others' opinion, sci-fi culture, or can be tempered by the user experience [11]. On the other hand, *satisfaction*, is regarded as a transient, experience-specific affect. One can have a pleasant experience with a product, but still feel dissatisfied if it is below expectation [13–15]. Thus, *experience* is what connects expectation and satisfaction [5].

### 2.2 Expectations and Satisfaction Towards Robots for Education

The concepts of expectation and satisfaction have been studied in teacher-student interactions in different educational settings, such as online education [10], e-Learning [16] and traditional classrooms [1]. Research seems to show that student's perceived satisfaction derives from different factors, such as the way the tutor's knowledge is transferred to children, how feedback is used to support and facilitate learning, and the level of interaction [10]. Thereby, the tutor's competencies and capabilities constitute some of the factors that will influence not only the satisfaction that children have regarding such an experience in an educational context, but also their learning. In the context of HRI, different projects are developing robotic tutors to support and assist children during their learning process (*e.g.,* CoWriter project[2]). Also, Alves-Oliveira and collaborators (2014), have explored the expectations of children towards a robot that can interact with them in their own classroom, concluding that children's initial expectations can help to identify the usefulness of robots [2]. In this sense, the study of expectation and satisfaction towards robotic teachers and/or tutors in the context of learning environments can be import predictors of children's learning outcomes and of their evaluation of the experience. Moreover, it is also important to consider the concepts of expectation and satisfaction for other HRI environments, in which the design of social robots with end-users is timely important when shaping the future of this technology.

## 3 Methodology

This study took place in a school, where children performed a collaborative learning activity about sustainability in a reserved area of a classroom. For each session, a pair of children interacted with the robotic tutor. Together with them, the robot acted as the tutor for the learning environment, and played *EnerCities*[3], which is a collaborative multiplayer serious game for learning about sustainability that is being used in the EMOTE project.

### 3.1 Participants

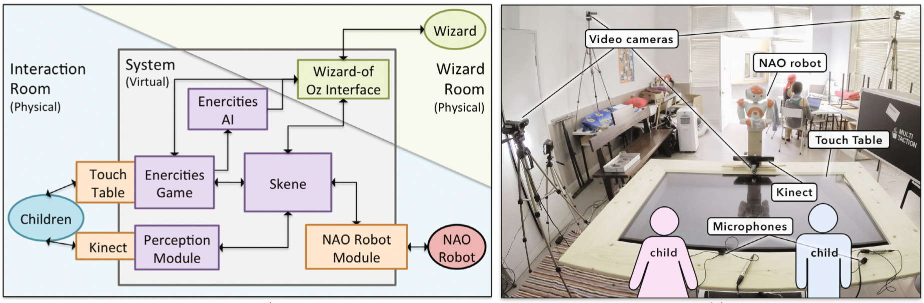
The study sample consisted of 56 children (30 male, 25 female, 1 unknown) aged between 14 and 16 years old ($M$ = 14.81, $SD$ = .48). The children that participated in this research had consent forms signed by their caregivers and assented to participate in the activity.

### 3.2 System Architecture and Set-Up

The robotic tutoring system used in the study follows the extended SAIBA model for intelligent virtual agents [18] and is composed of a NAO Torso robot from Aldebaran Robotics; an interactive touch table running *EnerCities*; four video cameras; two lavaliere microphones; a WoZ interface; and a recorder (Fig. 1.a). The children interacted with the system (see Fig. 1.b) both through *EnerCities*, and through the system's perceptive capabilities. The system interacts back through the robotic tutor, which performs social, expressive and game-play

[2] CoWriter project: http://chili.epfl.ch/cowriter
[3] EnerCities: http://www.enercities.eu/

related behaviour. The perceptive capabilities of the system includes detecting and tracking the children's head location, gaze direction, eyebrow movement (AU2 and AU4 [9]), and which child is currently speaking. This is all performed by the *Perception Module*, using the Kinect and the lavalier microphones.




a) b)

**Fig. 1.** a) Real environment setup. b) System architecture

The multimodal expressive behaviour (e.g., speech, gaze, animation) is managed by *Skene* which also includes a Gaze-state-machine, allowing the embodiment to perform semi-autonomously [18]. It is fed with information from the *Perception Module* and students' game-play actions from *EnerCities* to autonomously manage timing and expressive resources.

The robot's collaborative AI is a module capable of informing the game-playing and pedagogical decision-making of the robotic tutor that performs autonomously. The AI also incorporates a social component that continuously monitors each player's actions and automatically adjusts the tutor's strategy in order to follow the group's "action tendency" [20]. The Wizard was a researcher that was in a completely separate room, controlling the robotic tutor's high-level expressive behaviour (e.g., the timings to perform pre-defined utterances), using a specially designed user-interface. The AI selects a game move and makes it available for the Wizard to perform at the appropriate moment. This allows the Wizard to control the flow of interaction along with the flow of the game, without having to decide upon the game state and game actions. Finally, low-level and contingent behaviours remain autonomously controlled by *Skene*, which acts according to the high-level decisions performed by the Wizard and events triggered from the *Perception Module*.

### 3.3 Measures

To evaluate children's expectations and satisfaction, a TSES was created inspired in the Bhattacherjee and Premkumar (2004) scale [6]. Our scale was developed addressing aspects that inform about the state of the robotic tutor's development, in order to support further refinement. The TSES is composed of 10 questions allocated in 2 dimensions: *Capabilities* and *Fictional view* of the robotic tutor. It was used as a baseline questionnaire to measure children's expectations before seeing and interacting with the robotic tutor. Then, the TSSS was used as a post-questionnaire, applied after the interaction, to understand how children's subsequent satisfaction performed. Each scale is composed of equal questions to secure comparison between expectations and satisfaction, with different verbs tenses to meet different temporal experiences with the robotic tutor [4]. Children could rate their expectation level in the TSES in a 5 point type-Likert scale, ranging from 1 - *Very low expectation*; 2 - *Low expectation*; 3 - *Neutral*; 4 - *High expectation*; 5 - *Very high expectation*. The same Likert scale was used for the TSSS, substituting the word "expectation" for "satisfaction".

In order to understand whether the items of the scale were internally consistent, a Cronbach's Alpha was run. The scales had a good level of internal consistency for the 5 items of the *Capabilities dimension* ($\alpha = 0.770$) and for the 5 items of the *Fictional view dimension* ($\alpha = 0.749$) [8]. Thereafter, the *Capabilities dimension* served to inform about the expectations that children had towards the robotic tutor's capabilities, and how their satisfaction performed after the interaction experience. An example of a question that aimed to evaluate the expectation towards the robotic tutor's capabilities is the following: "I think the robotic tutor will be able to understand me." The *Fictional view dimension* relates with impressions created mostly by sci-fi culture, such as movies and novels, and an example is the following: "I think the robotic tutor will be similar to the robots I see in movies.". In addition, two more questions regarding the robotic tutor's *Competencies* were administrated: 1) "I think the robotic tutor will be a good game companion."; 2) "I think the robotic tutor will be the one that plays better.". The latter questions served to understand the perception that children had on the performance of the robot.

### 3.4 Procedure

The pair of children was invited into a separate room where they had no contact whatsoever with the educational setup, including the robotic tutor. This was a constraint to ensure that children's expectations were not influenced by any previous contact. At this point, the TSES was individually and separately applied to each child. After completion, the pair of children were led to the main room where the interaction with the robotic tutor took place. Children engaged in interaction in the real context of use for 20 minutes playing the EnerCities game with the robotic tutor. For this period of time, children were left alone in the main room with the robot, being able to freely interact and communicate with it. A researcher partially controlled the behaviour of the robot from a different room, in a WoZ methodology experiment, meaning that children were not aware that a third person controlled some of the behaviours of the robotic tutor. The game-play ended at the instruction of the robotic tutor. Afterwards, a researcher invited the participants to enter the same initial room where the TSSS was individually applied to each children.

[4] The TSES and the TSSS are available here: http://gaips.inesc-id.pt/~poliveira/Alves-Oliveiraetal.2015.pdf

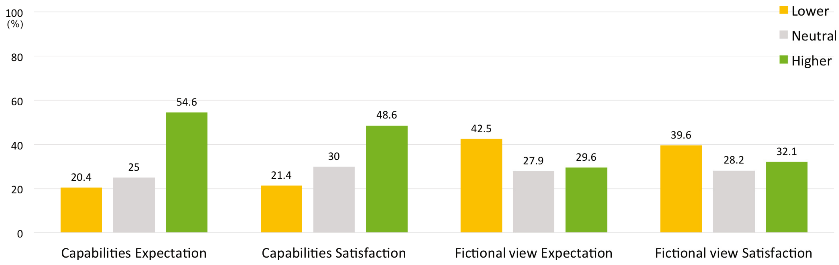



**Fig. 2.** Expectation and satisfaction of children towards the robotic tutor's capabilities and fictional view.

# 4 Results

To better understand the distribution of the results, data was re-arranged in 3 new categories, with a range of *Lower Expectation/Satisfaction* (scores below 3 in the initial 5 point type-Likert scale were clustered), *Neutral Expectation/Satisfaction* (scores equal to 3); *Higher Expectation/Satisfaction* (scores over 3 in the initial scale were also clustered).

## 4.1 Expectations and Satisfaction Towards a Robotic Tutor

Results seem to indicate that the children mostly had lower expectations about the robotic tutor in fictional terms (42.5%) and had higher expectations about the robotic tutor's capabilities (54.6%), whereas some of the children were neutral in terms of the expectations both towards the robotic tutor's capabilities (25.0%), and fictional view (27.9%) (see Fig. 2), which partially corroborates our first study hypothesis, which states that expectation of children would be high as robots are part of sci-fi culture. Regarding the satisfaction levels, results seem to suggest that when evaluating the robotic tutor after having experienced it, children's satisfaction levels seem to follow the expectations they previously had (see Fig. 2). This suggests that the majority of children who had higher expectations about the robotic tutor's capabilities (54.6%), seem to sustain higher satisfaction levels after the interaction (48.6%). Regarding the expectations of fictional view, results suggest that children had both higher (29.6%) and lower expectations (42.5%) of sci-fi culture towards the robotic tutor. The subsequent satisfaction indicates that children continued to have a mix of higher (32.1%) and lower (39.6%) satisfaction when evaluating this dimension. Thereby, the overall satisfaction towards the robotic tutor capabilities is higher, with no significant results between expectation and satisfaction levels. These results corroborate our second study hypothesis, which states that children will detain high satisfaction levels when evaluating the capabilities of a robotic tutor, after having experienced it.

In sum, the results of one iteraction seem to show that the current capabilities of the partially autonomous robotic tutor are at an appropriate level of


**Fig. 3.** Differences in expectation and satisfaction with experience.

development to sustain a collaborative educational interaction between an artificial tutor and students in a school classroom. Children seem to have had a positive experience of the interaction, as their expectations were accompanied by high levels of satisfaction. In addition, children's fictional views had lower levels, translating to more realistic expectations towards this technology.

A statistically significant difference was also found for the additional questions regarding aspects of the perceived competence of a robotic tutor, suggesting the interaction with the robotic tutor elicited a statistically significant change in the scores of satisfaction in comparison with expectation (Z = -3.127, $\alpha$ = .002). Therefore, the majority of children expected the robotic tutor to be a good game companion (75.0%) and after the interaction almost all children revealed higher satisfaction levels towards the tutor's competence (94.6%) (see Fig. 3). For the second question that assesses the competence of the robotic tutor, a significant result was also found (Z = -2.636, $\alpha$ = .008), revealing that the majority of children expected the robotic tutor to play best in the collaborative serious learning game about sustainability (69.6%), showing a significant decrease in their satisfaction after the interaction (50.0%). This result goes in line with the design process, as the robotic tutor had been developed to be a peer companion in the serious game, guiding children through the game rules and dynamics, but at the same time, having a similar hierarchical role in the game.

## 5 Conclusions and Future Work

This paper focuses on expectation and satisfaction in HRI and presents a novel metric for HRI. It aimes to address *expectations* and *satisfaction* of children towards an empathic robot tutor being developed in the EMOTE project to be included in an educational environment. The study of these concepts is crucial when developing a robotic tutor, as students' expectations and satisfaction are important in education [1], being predictors of learning outcomes [10]. To measure expectations and satisfaction, a TSES and a TSSS were developed and applied *before* and *after* the experience of the interaction with the robotic tutor. The results show that children had high expectations about the robotic tutor's capabilities, being followed by the same high levels of satisfaction. This result informs us that the behaviours of the robotic tutor in a 20min-interaction in a learning environment seem to meet expectations by their end-users. In addition, this suggests that state of the development of the partially autonomous robotic tutor for the classroom seems to be in an appropriate state to enable small group interactions with children. Results also show that the expectations regarding the fictional view of the robotic tutor are lower and remain lower after the interaction, which means that although children are exposed to sci-fi media, their expectations seem to be adapted to reality.

Overall, the design methodology inspired in real teacher-student interaction seems to have positive outcomes when testing the robotic tutor in its future environment with its future end-users. However, other possible outcomes of results can emerge when applying the TSES and the TSSS in the design process of creating a robot. An example of another possible outcome can be finding that users have high expectations regarding the fictional view of a robot, and high expectations regarding its capabilities. If the satisfaction level of fictional view decreases (which means it becomes more adapted to reality and further away from sci-fi culture) and the satisfaction towards the capabilities of the robot also decreases, this shows that the capabilities for the social robot do not meet users' expectations, suggesting the need for more development and refinement of its behaviours. Moreover, by looking at the items of the capabilities dimension, details about the capabilities that do not meet expectations can be identified.

Since the future of HRI will mostly be in people's homes and personal lives, our belief is that in order to build and create a valid futuristic technology that generates a positive experience and provides satisfaction to users, it is essential to involve them throughout this creative process. By measuring users' expectations and satisfaction, we are bringing input from the real-world users and stakeholders as co-designers of their future technologies.

In the future, we aim to measure expectation and satisfaction in a totally autonomous robotic tutor to understand how artificial social decisions are perceived by users (e.g., timing), and how satisfied they feel towards them, providing insights about the design over time. Also, we will explore the relation between expectations, satisfaction, and children's learning outcomes.

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