Title: Designing a socially assistive robot for education through a participatory design approach: Pivotal principles for the developers

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Designing a socially assistive robot for education through a participatory design approach: Pivotal principles for the developers

Abstract

Designing Socially Assistive Robots (SARs) for educational purposes can be a challenging task for developers. Developers need to identify the combination of a particular set of features to include in the design of a SAR. Participatory Design Approaches (PDA) can be a promising solution since stakeholders can suggest, through their involvement, the requirements that could meet their needs and expectations. Still, such approaches for designing a SAR for education are scattered and bewildering, focusing on aspects of the robot such as the role or the appearance. The current study aimed to map stakeholders' requirements regarding the design of a SAR exploited for educational purposes as well as to provide a set of guiding design principles for developers. A qualitative focus group discussion took place, and the participants were 127 (65 were female) stakeholders from five European countries, representing various affiliations in the field of education. A deductive qualitative content analysis approach revealed 121 themes of analysis, which fitted into 11 theory-driven categories regarding the use of the SARs in the class settings, their appearance, and their voice commands. Additionally, 46 themes of analysis were classified under five new categories following an inductive approach. The results of the deductive and inductive content analysis were further exploited in two Two-Step Cluster Analyses. The analyses revealed five tentative combinations of the dimensions exploited for the design of a SAR sketched by education stakeholders. The findings of the current study are discussed, providing pivotal guiding principles for the developers of SARs for education.

Keywords: Socially Assistive Robots; Social Role; Appearance; Voice; Stakeholders; Participatory Design approach; Developers.

1 Introduction

Socially Assistive Robots (SAR) has been a new trend in education in the last decade, reporting positive effects on students, such as an increase in academic performance or motivation [e.g., 1, 2] and behaviour change [e.g., 3, 4]. SARs could be used in educational settings fulfilling various needs of both students and staff with promising results [for a review, see 5]. To design a SAR for educational purposes that will meet the needs of the scholarly society is a challenge for the developers. A promising solution appears to be the involvement of various stakeholders, and end-users of the SAR in particular, to define their requirements. Indeed, there is evidence for stakeholders' involvement in the participatory design of SARs for educational purposes [6, 7, 8, 9, 10]. However, these participatory design approaches are scattered and bewildering. They usually focus on one aspect of SAR such as the social role [7] or the embodiment of the robot [6, 8, 9, 10], omitting other features such as the sophistication of interaction, which refers to interactive modalities employed in SAR such as speech or gestures. Hence, the existing evidence allows the developers to build a SAR for educational purposes considering the stakeholders' requirements only for a few design features. Through participatory design, the current study aimed to map stakeholders' requirements regarding designing a SAR exploited for educational purposes and provide a set of pivotal guiding design principles for developers.

1.1 The participatory design approach in designing learning environments

Many approaches describe user participation for designing products or learning environments (such as human-centred design, participatory design, research-based design, co-design, co-creation, user design, and learner-centred design), sharing similarities and differences among their principles. However, the majority of user participation approaches converge in leveraging from users' experience and knowledge to tailor the design of products or learning environments. The participatory design approaches involve various stakeholders and end-users in designing a new product, which will be utilised in education. The participatory design approach has been popular in designing new learning environments [11]. On the one hand, the participatory design offers researchers-designers the opportunity to involve stakeholders in various steps of the design [see 11], such as at the initial step of requirements and needs analysis or at the later step of prototyping the product through A/B testing and evaluation. On the other hand, it offers stakeholders and end-users a series of benefits. There is systematic evidence showing that innovative products for education designed through a participatory design approach: (a) achieve better product personalisation and adjustment to the users' needs, (b) assist users in the direction of avoiding inaccurate assumptions about their needs, (c) lead to appropriate designs [12, 13] and (d) increase their learning effectiveness [14]. The newly designed products formulate end-users who are highly motivated and engaged in the exploitation process of a product [14, 15], increase their satisfaction [16], and finally reduce the abandonment of the product [17]. Engaging students in the prototyping process of an educational robot has positive effects on students' attitudes towards educational robots and reduces robot anxiety [9].

1.2 The challenge to design Socially Assistive Robots

Social robots are defined as embodied agents designed primarily to interact socially with people, exhibiting peer-to-peer interaction skills [20, 21], and they can recognise, communicate, and learn from each other [18, 19, 20]. Socially Assistive Robots (SARs), in particular, are those social robots supplied with the ability to assist people through close and effective interaction with them while achieving measurable progress in situations like convalescence, rehabilitation, training, and education [22]. SARs for education can offer adaptive and personalised learning by exploiting intelligent tutoring systems, which integrate learners' preferences, analyse individual learning data, identify knowledge deficiencies, and employ appropriate strategies to present the knowledge to the individual learner [23].

The social role and assistance expected from the SAR within a particular environment and group determine the decisions during a SAR design process. The designer should decide the characteristics that the SAR should have to effectively meet the requirements of the social interaction and assistance concerning a specific target group and environment. However, the designer has a variety of potential features spanning across various dimensions and should select those features that could achieve the optimal result for the particular social role and environment. Fong, Nourbakhsh, and Dautenhahn [20] sketched out eight dimensions that a designer should consider, before deciding the design of the social robots: (a) embodiment (e.g., morphology – human-ness *vs* robot-ness, anthropomorphic, zoomorphic, caricatured, and functional), (b) emotion (e.g., artificial emotion, emotions as a control mechanism, speech, facial expression, body language), (c) dialogue (e.g., low-level pre-linguistic proto-language, non-verbal, and natural language), (d) personality (e.g., tool-like, pet-like, cartoon, artificial being, human-like robot), (e) human-oriented perception (e.g., people tracking-speech recognition, gesture recognition, facial expression-face detection and recognition, facial expression, gaze tracking), (f) user modelling (e.g., able to interpret and react to human behaviour by modelling), (g) socially situated learning (e.g., able to interact with its social environment to acquire new competencies – robot social learning, imitation) and (h) intentionality (e.g., attention, expression- robot provides cues that enable adults to interpret its actions as intentional).

Feil-Seifer and Mataric [22] described four additional dimensions that the designer of a SAR should consider. These include (a) the user population that is the target group (e.g., elderly, individuals with cognitive disorders, individuals with physical impairments, individuals in convalescent care, students), (b) the task expected by the SAR (e.g., tutoring, physical therapy, daily life assistance, emotional expression), (c) the sophistication of the interaction (e.g., speech, gestures, or a direct input through a mouse), and (d) the role of the SAR (i.e., the task for the specific group and the impression that the SAR gives through the appearance and the behaviour. Moreover, developers could consider other taxonomies describing requirements regarding the design of autonomous robots [24], which emphasize more on hardware and software requirements that are necessary for a robot to be endowed with autonomy.

It is evident that the developers should decide about a variety of parameters. They should choose the values with the optimal effect regarding the particular intended use and the role assigned to the robot for the target population. Furthermore, they should consider the sophistication of the expected interaction and the complexity of the social environment [20]. There is evidence that the quality of the interaction is sensitive to the values the various features might have. For instance, the dimensions of the head, the number of facial features [25] as well as the friendly or angry personality [26] affect the quality of the interaction. Moreover, the same robot is perceived differently by children and adults, affecting the interaction's quality [27]. It should be noted that the design of a SAR to be used in autism therapy has different demands than a SAR designed to be used in a group of typical children [e.g., 28].

The involvement of stakeholders in the design of the SAR is crucial. Stakeholders could help the developers sketch the requirements and reduce the potential combinations across the various dimensions to those that are necessary for assisting the target population, considering, at the same time, the sophistication of the expected interaction and the complexity of the environment.

1.3 Designing Socially Assistive Robots for education

The design of a SAR for education becomes more complicated as beyond the characteristics one should consider for a SAR, the designer should also consider (a) the needs (cognitive, metacognitive and emotional-motivational) of the students or the teachers (e.g., keep records) it will assist, (b) the frequency of the interaction and the its duration (e.g., in case of a prolonged lasting use the SAR should be able to improve and adapt its skills to meet the needs of the groups as these are changing over the time – ("epigenetic robot", [29]), (c) the architecture of the robot that will support the interactive mode [e.g., 30], (d) the particularities of the domain or the subject of the learning activity (e.g., linguistics might have different demands than STEM subjects), (e) the learning environment in which the learning will take place (e.g., individual use or use in groups, use in the formal or in the non-formal education), (f) the role and the behaviour of the robot during the learning process (e.g., [31] defined three prominent roles and behaviour for the robots during the learning activity: a tutor, a peer, or a tool), (g) the ethical perspective of the Human-Robot Interaction [32] and finally (h) the evidence from the research on involving SARs in education. As diverse learning theories create different needs to be covered in the teaching process, the designer should also be aware of the dominant learning theories and didactical approaches teachers use to design their teaching.

1.3.1 The involvement of stakeholders in the design of a SAR for education

The attempts to design a SAR for the education involving stakeholders showed that crucial information on building a robot could be provided to the developers. Nevertheless, previous research has at least three shortcomings.

First, although scholars were keen to capture the stakeholders' representations for the robots and thus the different content they have for the robots, their studies had a couple of weaknesses. They used the same labels to describe very different representations, or they used different taxonomies to describe the stakeholders' expectations for the role of the robots. For instance, Mubin, Stevens, Shahid, and Mahmud [31] classified the robots based on their involvement in the learning task. They used the terms "tool" (for the robots with a passive role), "peer" (for the robots that can take the role of co-learner, peer, companion, and care receiver) and "tutor" (the robot can take the role of an autonomous mentor). However, elsewhere when the researchers asked teachers to sketch the features from a "tutor" robot in their class, they integrated features corresponding to different levels of involvement in their representations. Teachers denoted that the robot should be dependent on them (conveying educational material to the students) while having some automatic responsibilities (such as implementing a sort of automated assessment database) or acting as a "peer" that can guide and motivate students through several learning tasks [33]. The above indicates that the classification and the labelling which scholars use for various robots do not correspond to the representations stakeholders have when they use the same terms. Thus, further exploration is needed to comprehensively conceptualise the roles that could be assigned to a SAR.

Second, the involvement of stakeholders showed that the features that sketch the robot are biased to the group of those who participate as stakeholders and can be identified as members of a community or a workplace. Evidence from the field of care robots revealed that stakeholders engaged at a workplace usually hold different mental models [or incongruent technological frames, see 34] depending on their role in the workplace. In the field of education, teachers expect a different assisting role of the SAR than their students. Students, in particular, expected the SAR to support them by providing information, learning consultations, assistance during studying school subjects and also to act as a tutor that facilitates them in improving their grades [35]. Teachers perceived the SAR as their assistant in their pre-class preparation (e.g., search for teaching materials online and organise them), in-class assistance (e.g., monitor group discussions, detect distracted students or students with understanding difficulties) and after-class organisation (e.g., generate homework, manage schedule and student's portfolio, send reminders). Further, they considered the SAR as an assistant that could be running errands for them, transferring documents, or sending messages and memos to parents [7] while motivating their students [33].

Additionally, the teachers, having in mind the different educational needs as children grow up, expected the SAR to be adaptable to the students' age group. For instance, when experts, researchers, and teachers were involved in the participatory design to build a SAR as a companion for different age groups, they suggested for pre-schoolers a robot that they could play games with. For the high-school students, they suggested a SAR being able to help them with their homework and time or diet management [7]. Moreover, when students are asked for the features that are important for the specific role of a robot (e.g., for a companion), children under nine years old focus more on appearance, while older children and adults tend to focus on skills and functions [36]. At the same time, the previous experience with robots can influence the children's appearance expectations of a SAR [37]. Finally, when experts, researchers, and teachers are involved in the participatory design of a SAR, the result is a SAR with a higher level of intentionality, able to act as a "learning counsellor" by supporting the personal reflection and self-regulation of the user during learning. Additionally, the designed SAR provides counselling regarding learning performance and professional career development as well as constructs a model for the students' learning profile, informing them about their learning weaknesses and strengths [7]. So, as the above indicates, the stakeholders' synthesis seems crucial in having a comprehensive view of the requirements that should be considered for designing a SAR for educational purposes. In other words, a broad group of stakeholders, including students from a spectrum of ages, might be more informative for capturing the needs a SAR would fulfil.

Third, the studies reported a list of features that stakeholders expect from a SAR in education. Then researchers attempted to group them in a meaningful way based on predefined taxonomies. Some scholars classified the stakeholders' responses for features attributed to SARs in education by applying statistical analyses to their data. For instance, Woods [38] applied a Principal Component Analysis to reveal the stakeholders' responses for the personality attributes. This study showed that stakeholders endorse a different combination of facial features, gender, and body shape for the same personality of the robot. Thus, the use of such statistical analyses enables developers to shape a combination of the features that should be used to build a SAR based on the intercorrelations of these features on their data (i.e., stakeholders' requirements) and not on the predefined taxonomies. However, to the best of our knowledge, there is no study applying statistical analysis to build a SAR, which will be used for educational purposes. Therefore, future research, using statistical analyses, should reveal the combination of features such as the role, appearance, and communication features from crucial dimensions for the SAR, which will be used in educational settings.

1.4 The current study

It is evident that the design of a SAR for educational settings is a challenge for robot designers. They should define the role the SARs will have in the class following the students' requirements, teachers, and learning topics. Additionally, from an extensive list of dimensions, they should decide on the appearance and the communication features that will bring the optimal results in education and make the SAR an efficient educational agent in the class. The participatory design approach could help to reduce the variety of possibilities and design a SAR close to the end-user's requirements.

The common practice in the previous attempts to involve stakeholders in the design of a SAR showed a lack of a common understanding in the conceptualisation of the SAR agents that could be used in education. Moreover, there is evidence that the stakeholders involved in the participatory design might bias the SAR design. Finally, most of the previous attempts to capture the end-user's visualisations for the SAR were limited in creating a list of the potential features the robots might have. The designer of a SAR, however, needs evidence about the combination of possible features to build a SAR that will serve its role in education.

In the current study, we were interested in mapping the stakeholders' requirements for a SAR to be used in the typical class settings within the formal education for age groups between 10- and 18-year-old students. The study is innovative for five main reasons. First, the primary purpose is –through the participatory design approach– to provide the designers with the necessary evidence that will allow them to design a SAR suitable to be used within the typical class settings. Second, to enhance the study's ecological validity, at least within the European continent, a broad range of stakeholders from five European countries (Belarus, Finland, Germany, Greece, Spain) involved in an EU project expressed their wishes and requirements. The stakeholders were teachers and school principals from different educational levels, students from various age groups, parents having students in different educational levels, experts from the market sector. Third, instead of asking stakeholders for limited features, we were interested in mapping their wishes and requirements regarding the holistic design of a SAR and particularly (a) the plausible uses and the social roles of the SAR, (b) the appearance as well as (c) the verbal communication features. Fourth, instead of having a list of requirements for the SAR as the outcome of the participatory design, we were interested in extracting a combination of possible features that will enable the developers to have a comprehended vision for the SAR, which is going to be used in education. Fifth, as it is possible to have more than one combination, the current study aimed to explore whether stakeholders prefer different combinations.

2 Method

To meet the objectives of the study, a qualitative focus group discussion approach was employed. The focus group involves a structured discussion with a small group of people, moderated by a facilitator or a team. Using a set of open-ended questions, the focus group aims at generating qualitative data on a precise topic of interest [39, 40, 41]. Focus groups were employed because it is considered as a suitable method for exploring participants' knowledge and experiences, while they can be used to examine not only how participants think but also why they think in a particular way [41, 42].

2.1 Material for data collection

The data collection instrument was primarily developed in English and then was translated into five local languages of the stakeholders. Due to the explorative nature of the study, open-ended questions were employed [42, 43, 44]. Employing any priming to broaden participants' imagination regarding the (dis)embodied nature of the robots [e.g., 45] or the nature of their intelligence [e.g., 46, 47] could potentially be a source of bias and could hide the possible differences between the various groups of stakeholders. Thus, we provided no concepts or definitions to avoid influencing or limiting their personal views, ideas, or wishes [48]. Participants were asked about the potential use of the robots, their appearance and the voice commands of the robot.

2.2 Sampling strategy and participants

Purposive sampling strategy, one of the non-probability sampling methods often adopted in qualitative studies [49], was employed to select those participants who are relevant to a specific research topic [50]. To identify stakeholders engaged in an education context, we originally constructed a model to classify all potential groups in three different levels of involvement. Stakeholders were classified according to their interest to SAR as following: (a) direct interest (i.e., students, teachers, parents), (b) intermediate interest (i.e., policymakers, principals, and administrative staff, learning and instruction experts, HEIs representatives), or (c) indirect interest (i.e., stakeholders from research centres, companies, chambers, professional associations or the authorities' benefits and interests towards the design of a SAR for exploitation in education) to the SAR. The invitation (and engagement) of a wide range of stakeholders in the design of the SAR is expected to bring a variety of information, expertise, and experience.

As a baseline for the sample size, we decided to engage two participants, one female and one male, from the three levels (i.e., direct, intermediate, and indirect interest) of stakeholders involved from each country. In this way, a theoretical saturation would be achieved [48]. Although the sample size and synthesis of focus groups was considered adequate for the exploratory nature of the study, the sample of the current study was convenient, while the voluntary response sample and the inferences from the study should be considered cautiously. Following the above procedure, 127 (female *n*= 65) stakeholders were involved in the study from five countries, namely Belarus, Finland, Germany, Greece, and Spain. The five countries were members of a consortium working in a HORIZON2020 EU project. Table 1 describes the distribution of the participants per category of the stakeholders' group and country. Each country conducted three (i.e., one for each level of education; primary, lower secondary and upper secondary education) focus groups (15 focus groups in total). Participants from each category of stakeholders were invited to each focus group.

Table 1: The composition of participants involved in the focus group participatory design sessions per country and stakeholder category

Stakeholder group	Belarus	Finland	Germany	Greece	Spain	Total
Primary School students	2	4	12	2	4	24
Lower secondary school students	6	5	-	2	5	18
Upper secondary school students	2	2	5	2	4	15
University students	5	2	2	-	2	11
Teachers	3	3	4	6	2	18
Principals	3	2	1	3	2	11
Parents	4	6	2	6	4	22
STEM companies' representatives	2	2	-	3	1	8
Total	27	26	26	24	24	127

2.3 Data collection process

An invitation letter was developed to invite stakeholders to the focus groups [51, 52]. Additionally, the experts prepared the data collection instrument and general guidelines [53] to implement the discussions. Moderators of the discussions were social science researchers familiar to focus groups implementation. All participants signed informed consent forms to ensure their participation in the focus group [51, 54]. Legal guardians signed the informed consent forms on behalf of minor participants, namely all students under 18-years-old.

Three (i.e., one for each level of education; primary, lower secondary and upper secondary education) focus groups per partner country (90-minute average time each) took place. Two moderators facilitated the discussions, which were conducted in the native language of each country. A code was provided to the participants to ensure their anonymity. Experts described the overall project, part of which was to build a SAR for exploitation in formal education settings. As we were interested in capturing possible differences in the stakeholders' views, no priming was exploited, which could enlarge participants' imagination [48] and homogenize their wishes. Moderators guided the discussion without expressing their views, which might have influenced participants [55, 56]. Concurrently, they clarified to the participants that all thoughts and opinions were accepted. Participants provided their answers in a written form, while the overall discussions were audio-recorded.

2.4 Data analysis

Qualitative content analysis – an appropriate method for analysing written, verbal, or visual communication [55] – was employed for the current study with the computer-assisted qualitative data analysis software ATLAS. ti v7.5.7 [see 56 for a review on a previous version of ATLAS]. The qualitative analysis aims at classifying large amounts of text into several categories, which share similar meanings and interpret a broad context [57].

The data were analysed employing the deductive approach and previous theoretical evidence regarding the design of a SAR [57, 58]. Data from each country were translated into English, and then they were grouped in a united data pool. A researcher read the data to become familiar with how participants expressed themselves. The participants suggested 381 wishes on the three topics of discussion. The *theme* was identified as the unit of analysis [55], and 121 themes were identified on the data. A structured categorisation matrix was developed considering the taxonomies that Fong and colleagues [20] and Feil-Seifer and Mataric [22] proposed regarding the design of social robots and SARs, respectively. Two experts, one in Psychology and one in Human-Robot Interaction, classified the 121 themes in accordance with the subcategories (and hence categories) of the theory-based formulated matrix [55, 56]. The experts classified only the 75 themes in 15 subcategories that fitted into 11 categories. The inter-rater agreement was measured with Cohen's kappa coefficient [59] and found to be excellent among the three different discussion topics regarding the SAR (the use of social robot κ=0.97; the appearance κ=1.00; the voice commands κ= 0.96).

Still, 46 themes were unclassified because they did not fit in the subcategories and categories of the structured matrix. Thus, based on inductive content analysis principles, the two experts suggested new subcategories and categories, and the matrix was extended to include those ones, too [58]. Specifically, we considered three criteria for the development of the new categories and subcategories. The first one was the relevance of the argument and the added value to the existing taxonomies regarding the SAR design. The second concerned the frequency of appearance of the uncategorised themes. If the frequency criterion was not satisfied, the importance and emphasis of the stakeholders' argument (i.e., density) were considered. Namely, some stakeholders made unique contributions of ideas and wishes relevant to the topic, but these were endorsed only by a few or no other stakeholders. In such cases, although the frequency criterion was not satisfied, the unique themes were classified under a category or subcategory because of their importance for the unique stakeholders. Thus, the density criterion was satisfied. Additionally, excluding these unique themes would lead to the underrepresentation of specific stakeholders within the data. This procedure resulted in the construction of 22 new subcategories.

The ratters classified 10 of the subcategories in the pre-existing theory-driven categories. For the rest 12 subcategories, five new categories were developed. The inter-rater agreement among the ratters was excellent (the use of social robot κ=0.98; the appearance κ=0.97; the voice commands κ= 0.96). After a discussion between the two ratters, an entire agreement was reached. The Appendices present the categories, subcategories, and key themes identified from the content analysis. The new categories and subcategories that emerged from the current data are italicized.

3 Results

The analysis revealed 121 *themes* in total; 40 for the SAR's role, 37 for the appearance and 44 for the voice commands. Many of the themes were similar in meaning. Thus, for each topic, the themes were grouped into subcategories and categories. The categories reflected the different dimensions or variables that denoted when the stakeholders were thinking about the topic. In the Appendixes, the categories and the subcategories within each category are presented in terms of the highest frequency among participants' statements. Additionally, Appendixes include the stakeholder's endorsements of each subcategory.

In the following sections, we will present the categories and subcategories description [53]. Finally, we will present two exploratory Two-Step Cluster Analysis to investigate whether participants shared patterns of combinations when conceptualising socially assistive robots employed in educational contexts.

3.1 Content analysis

3.1.1 The use of the SAR

Regarding the first topic of the focus group discussion, namely the use of the robots, participants quotes were grouped into 22 subcategories overall, which were classified into eight categories (see Appendix 1 for the list of subcategories and the categories defined). Six out of eight categories were created following a deductive approach using the taxonomies the scholars had already suggested as the dimensions that one should consider before designing the social robots [20] or socially assistive robots [22]. In comparison, for the two categories, an inductive approach was followed.

The first category revealed from the deductive approach includes themes with high-density concepts (e.g., assist, support) referring to the robot's assisting role, and mainly the task of the robot for the specific group [22]: to assist and support teachers and students in learning. The category also describes one of the social roles for SARs in education identified in the literature [e.g., 7], and we named it accordingly, "*The role of Assistant in Learning*". Two subcategories were classified under this category. Participants more frequently cited the first one and described that the robot could act as a learning pal for students, as an assistant during the learning process, or as an assistant supporting students during their homework. Most of the stakeholders used this type of themes to refer to the role of the SAR in education and especially its role for the students. We named this subcategory "*Assistant for students*". The second subcategory was devoted to themes referred mainly to the teachers' support. The name given was "*Assistant for teachers*" to denote that the role of the SAR is determined by its task to assist the specific group of teachers [22].

The second category in endorsements included themes referring to the potential tasks that the robot expected to perform considering the end-user's needs. The themes were indicative examples of tasks that the robot could perform, such as play, assist in daily life or learning, be employed as a tool, have fun with, be employed in learning and instruction of particular subjects and skills. This category has been described by Feil-Seifer and Mataric [22] as a dimension for consideration for the design of a SAR. Thus, following their suggestion, we named the category "*Task Expected by the SAR*" [22]. Nine subcategories were classified under this category. The first subcategory with most endorsements considers that the robot can assist individuals in daily activities (a servant) and control applications. This subcategory, which was named considering the taxonomy proposed by Feil-Seifer and Mataric [22] as "*Daily Life Assistance*".

Twelve more themes were classified through the deductive approach in the category "*Task Expected by the SAR*". However, the raters did not classify them into subcategories that could fit the existed taxonomies. Thus, following an inductive approach, they suggested eight new subcategories that belong to this category. The first subcategory, which was generated through the inductive approach with the majority endorsements, described tasks such as using the robot as an educational game, playing with the robot, and learning through playing with the robot. We named the subcategory "*Play*".

The second subcategory included themes denoting that the robot could be used for learning in ICT and STEM disciplines. The subcategory was named "*Learning ICT/STEM courses*" to denote that stakeholders would use the robot to instruction ICT and STEM-related disciplines.

The third subcategory included themes describing the use of the robots as a device or an application and a tool for learning. A few participants conceptualised the robot as a tool employed similarly to mobile devices or as a teaching tool. Therefore, the subcategory was named "*Tool*".

The fourth subcategory considered stakeholders' wishes to use the robot in learning. However, additional information on a particular role that the robot should have during learning is not provided. Still, the robot is perceived as a source of information similar to search engines and as a medium for learning through the teaching by learning strategy. We named the subcategory "*Learning*".

In another subcategory, three endorsements were grouped because they perceived the robot as a medium through which the user can have fun. Thus, this subcategory was named "*Fun*" to denote that the robot's task is to have fun with the end-users.

Three more subcategories were generated that were classified under the category "*Task Expected by the SAR*". Under these subcategories, only four themes were grouped. The first subcategory included two endorsements suggesting that the robot could teach multiple disciplines. Therefore, the subcategory was named "*Multidisciplinary learning*". The second subcategory included one quote wishing for a robot that students could use to learn transversal skills. The subcategory was named "*Skills Learning*". Last, the final subcategory included one endorsement describing that the robot would be used for problem-based learning. Therefore, the final subcategory of the "*Task Expected by the SAR*" was named accordingly "*Problem Based Learning*".

The third category with more endorsements includes themes that perceive the robot as an agent like humans, which stakeholders could use as a teacher, tutor, or mentor in a class or a friend in life. The stakeholders referred explicitly or implicitly to the SAR as an intentional agent with goal-directed behaviour and higher-order human skills such as thinking, advising, and making decisions. Intentionality is among the dimensions that have been described by Fong, Nourbakhsh, and Dautenhahn [20] for the design of social robots. Thus, we named the category "*Intentionality of the SAR*" [20]. The themes included in the category were representatives of the "*Goal-directed behaviour*" [20] that denotes participants' intention, the robot to engage in higher-order cognitive skills and procedures. Indeed, participants wished the robot to think and motivate students, raise their interests, or advise them.

The fourth category included themes that referred to a human-like personality for the SAR, displaying human-like traits and qualities, such as being a friend, having a personality, rewarding students, being nice and acting as a helper. The category reflects the "*Personality*" dimension and the "*Human-like Personality*" in particular of the taxonomy suggested by Fong and colleagues [20].

The fifth category included themes that referred to the social robots' dimension described as "*Dialogue*" [20]. Two subcategories were classified under this category. The first subcategory with most endorsements considers that the robot should discuss with and provide feedback to end-users. This subcategory reflects the term "*Natural Language*" used in the taxonomy of Fong and colleagues [20] to denote that the robot can engage in dialogic verbal interactions and respond as it displays physical and perceptual capabilities like humans. The second subcategory referred to non-verbal communication, such as expressing emotions in a HRI through body language (e.g., facial expressions and body gestures) reflecting the "*Non-verbal*" dialogue dimension of the social robots [20].

The sixth category included themes that referred to in-class working modes (i.e., individually or in groups) to integrate the SARs that would be built up through the participatory design. This category of themes does not exactly fit in the existing categories. Thus, using an inductive approach, we decided to consider the category as an additional option of the category Feil-Seifer, and Mataric [22] proposed under the name "*User Population*", as it refers to the various populations of users that the SAR might work with. The stakeholders mentioned two options of them, "*Users in Group*" and "*Individual Users*".

The deductive approach enabled us to classify most of the *themes* in subcategories and categories. This classification was based on the previous taxonomies. Nevertheless, six more themes were unclassified. Following an inductive approach, two additional categories were created to group the themes that did not classify into the existing taxonomies. The first category referred to the fields where a robot could be employed. We named this category "*Field Example*". In particular, the stakeholders suggested that the SAR might be used in the field of care, work, in the education (general or special), and we created the subcategories "*Care*", of the "*Work*", in the "*Education*" or in "*Special Education*" respectively.

The second category we created following an inductive approach included themes regarding the risks that emerge from using robots. The risks, which were highlighted by the stakeholders, were related to the loss of human jobs, which is an outcome of integrating the robots into many enterprises' workforce. A subcategory holding the same name, namely "*Risks from using SARs*", was developed.

3.1.2 The appearance of the SAR

The second topic referred to how the robot might look like; in other words, to its appearance. Overall, 15 subcategories were grouped under six major categories to describe participants' wishes (see Appendix 2). Five out of six categories were created following a deductive approach using the taxonomies the scholars had already suggested as the dimensions that one should consider before the design of the social robots [20] or socially assistive robots [22], while for the one category, an inductive approach was followed.

The most popular category based on the deductive approach referred to the "*Embodiment*" of the robot, a theory-based category [20] that focuses on themes that describe the physical body and the robot's resemblance with other beings such as humans, non-humans, animals, or toys. This category included four subcategories. The first subcategory had the most citations from the participants and attributed human characteristics to the robot's body. We used the term "*Anthropomorphic*" provided by existing taxonomies [20] to describe the robot with a human-like embodiment. Nevertheless, few stakeholders expressed the wish for the robot to avoid having human embodiment. Thus, we created a second subcategory, the "*Non-anthropomorphic*", inductively to include this theme. The third subcategory included only a few citations focusing mainly on the description of the robot's body in terms of resemblance with living creatures such as animals and specifically pets. The existing taxonomies [e.g., 20] proposed the "*Zoomorphic*" embodiment type for robots that resemble animals and particularly domestic animals. The final subcategory of the "*Embodiment*" category included themes that attributed features of toys and animated or movie characters to the robot. In accordance with the previous taxonomies [20], we named these themes as "*Caricatured*" embodiment.

The second more popular category regarding the appearance of the robot (based on the deductive approach) was the themes referring to the robot’s mechanism to detect the human action, interpret and react to a behaviour. Specifically, stakeholders considered the robot’s appearance as something that can be changed, customised, and become adapted to end-users’ needs, tastes and suggestions. Fong and colleagues [20] used the term “*User Modelling*” to refer to a set of the social robot’s attributes enabling it to implicitly or explicitly describe the user or groups of users. They suggested that the user modelling might be defined as a priori (static) or might be learned through communication with the user(s) and thus be dynamic. Therefore, the subcategory was named “*Dynamic*” to denote the ability of the robot to achieve emotional attachment with the user.

Another category identified from the existing taxonomies [20] was the category of “*Personality*”. In psychological terms, “personality is a system of parts that is organised, develops, and is expressed in a person’s actions” [60] and, therefore, distinguishes individuals. Personality in social robots considers among others, (a) whether it will be designed to have some characteristics a priori or progressively learned; (b) whether it will mimic the personality of humans (i.e., human-like personality) or other beings (e.g., tool-like, pet or creature, cartoon-like, artificial being) or (c) whether it encourages a specific type of interaction [20]. Three subcategories were employed from the existing literature to classify the themes classified in this category. The first subcategory, which was more frequently cited among participants, includes themes that emphasized the use of the robots as tool-like smart appliances [20], exhibiting traits (e.g., dependability) usually associated with tools. Stakeholders viewed the gadgets, games, and possible applications the robot might be equipped with as an integral part of the SAR’s appearance. Thus, the robot would exhibit traits usually associated with tools that can perform service tasks on command, like smart appliances. Consequently, we employed the name “*Tool-like*” for this subcategory.

The second subcategory included items that attributed artificial (i.e., mechanistic) or literature and film inspired characteristics to the robot. We applied the name “*Artificial being*” [20] to this subcategory that described the robot in terms of artificial and science fiction characteristics. Nevertheless, one student did not endorse this idea of a robot as an artificial being. For that purpose, we inductively created a new subcategory named “*Non-artificial*” to highlight this perspective of the user.

Two categories that outline the appearance of the robot in terms of its voice and verbal communication were among the least popular categories. The first of the two has been described by Fong and colleagues [20] as the dimension of the “*Dialogue*”. The dialogue with the social robot might be at low-level (pre-linguistic), non-verbal, or using the natural language. The stakeholders in our study wished the natural language to be the feature of the SAR by referring to the ability of the robot to transform text to speech and speech to the text. Thus, we named this subcategory “*Natural Language*” [20] to denote the wishes referring to the robot’s ability to engage in query-response speech acts that approach the natural dialogue in an HRI.

The second category dealing with the voice and verbal communication of the robot refers to its ability to perceive the world as humans do and present similar perceptual abilities. This dimension refers to the “*Human Oriented Perception*” described in Fong and colleagues [20]. One participant (Participant 110) wished “the robot can understand voice commands”, meaning that the robot should have the ability to recognise human speech. Following the previous taxonomies [20], we named this subcategory “*Speech Recognition*”.

The deductive approach enabled us to classify most of the themes in subcategories and categories described in the previous taxonomies. Nevertheless, 24 of the themes were unclassified. Two of them (i.e., the non-anthropomorphic and the non-artificial being) were integrated into the existed categories.

The rest 22 themes were classified following an inductive approach, and they were all classified into the same category as they referred to the user-friendly appearance of the SAR. We named this new category "*User-friendly*". The appearance can be perceived as user-friendly when the end-user finds it appealing, mindful of end-users' needs and wishes, or intuitive since it can make sense to the average end-user. Thus, the category "*User-friendly*" does not refer to the features that support the function of the SAR but to the functional result of the appearance. This category included five new subcategories. The subcategory with the majority of endorsements referred to the robot's size and weight, namely for the robot to be small, of medium size, big size, or lightweight. Participants expressed wishes for the robot's size ranging from small to big size, but when they referred to the weight, they expressed their wish for the robot to be lightweight. Thus, we named this subcategory "*Size and Weight of the SAR*".

The second subcategory that emerged from participants' answers was related to the robot's ability to move alone or be transferred by the user. Stakeholders considered movement as an essential requirement of the SAR's appearance. Movement is perceived either as autonomous mobility of the robot or the possibility of it being transferred by the users. Thus, we named this subcategory "*Movement*".

The third subcategory in endorsements included themes that referred to the aesthetic aspects of the SAR's design: the robot should have an attractive, nice, modern, or straightforward but not scary design. We named this subcategory "*Aesthetics of the SAR*".

The following subcategory included quotes regarding the materials that should be employed for the construction of the robot. Thus, we named this subcategory "*Material for the construction of the SAR*".

The final subcategory with the fewest endorsements includes quotes that refer to the functionality of the robot. We named this subcategory "*Functionality of the SAR*".

3.1.3 The voice commands and oral communication of the SAR

The last topic participants expressed their wishes for was related to the voice commands of the robot. Following a deductive approach, the wishes were grouped into five subcategories that fit into four categories corresponding to dimensions, all described by Fong's s and colleagues' taxonomies [20] (see Appendix 3). The category with the majority of endorsements among the stakeholders referred to the robot's ability to perceive verbal communication with humans. These perceptual abilities correspond to the "*Human-oriented perception*" dimension suggested by Fong and colleagues [20] to describe the perceptual abilities that allow social robots to interact meaningfully with humans and perceive the world as humans do.

We defined two main subcategories within this category. The first one was the most popular and included items that described the process of enabling the robot to identify and respond to the sounds produced in human speech. Additionally, it included items describing the ease of use, controllability, and effectiveness of the robot's voice commands, *per se*. We named this subcategory "*Speech Recognition*" to denote that stakeholders wished for the voice commands of the SAR to be functional, easy to understand and use, enabling the robot to respond to human speech through speech recognition and vice versa. The following subcategory included only a few themes related to the safe use of voice commands. Stakeholders wished the voice commands of the robot to be used cautiously and securely to avoid any risks that could affect the end-users. Thus, the last category was named "*Types of Perception*" to denote that a robot would perceive the various types of how the end-users could use the voice commands.

The second major category that emerged regarding the robot’s voice commands was related to the robot’s ability to perceive human social behaviour. Among the items classified under this category were themes highlighting the robot’s ability to adapt and customise the voice commands to respond appropriately to a human need or behaviour. Thus, the category was named “*User Modelling*” [20] because, for the robot to respond appropriately to human behaviour, it has to model the user’s behaviour or a group of users. Only one subcategory was found under this category. It included stakeholders’ wishes for a SAR with adaptable voice and language depending on the end-users’ particular needs, thus being dynamic. Hence, following Fong’s and colleagues’ taxonomy [20], we named this subcategory “*Dynamic*” to distinguish it from the static, predefined features of the SAR.

The fourth category includes themes that denote how the voice commands would function and facilitate HRIs. Although para-linguistic social cues could be employed during HRIs, the current category included only the natural language as crucial for controlling a human-robot dialogue. Thus, following Fong’s and colleagues’ taxonomy [20], we named the category as “*Dialogue*” to denote the functionalities and exploitation of the voice commands, and we named the subcategory as “*Natural Language*” to stress the stakeholders’ wishes to use the natural language in communication with students.

The last category identified under this topic of discussion highlights how the robot’s voice commands can reflect emotions and different intonations. Stakeholders connected this feature with the voice rather than with the facial expressions or the body language. Following previous taxonomies [20], we named this category “*Emotions*” and “*Speech*” [20] the subcategory.

3.2 The Two-Step Cluster Analysis

In the previous section, we presented the qualitative analysis of the texts the stakeholders produced for using the SARs in the class settings, their appearance, and their voice commands. In each topic, the themes were grouped in subcategories, which were grouped in higher-order categories. These categories are the dimensions the stakeholders consider crucial for the topic, while the subcategories are the properties of these dimensions. Also, the specific themes are the values that the properties might have. Although this evidence is informative of the stakeholders’ requirements, a designer has no idea how to combine the dimensions from the appearance to the voice commands for each type of SAR to meet the stakeholders’ requirements. In this section, we will apply two Two-Step Cluster Analyses to our data to reveal tentative combinations of the dimensions for the type of SAR sketched by the stakeholders.

The Two-Step Cluster Analysis aims to identify homogenous groups of cases in a specific dataset. Cases in a specific cluster share many characteristics but, at the same time, vary significantly with objects that do not belong to the same cluster [61]. Two-Step Cluster Analysis was preferred over other clustering techniques because it selects the number of clusters automatically, and different types of categorical variables can be included in the analysis, such as binary and ordinal [61]. The first step in the two-step cluster analysis is to identify pre-clusters, which are treated as single cases in hierarchical clustering in the second step [62]. The Analysis was carried out with the Bayesian information criterion (BIC) [63]. The BIC criterion is employed when k parameters are included in the model to penalise the increase in the parameters. The BIC penalty term is larger than in the Akaike information criterion (AIC) [64]. The Bayesian framework derives from the subjective probability paradigm, where there is no notion of repeating an event of interest in the data instead of frequentist statistics and testing the null hypothesis [65].

According to Feil-Seifer and Mataric [22], the definition of the robot's role is essential for designing its appearance and interaction modalities. Thus, we decided to define firstly the roles the stakeholders wish for the SAR and then to examine the features that they combine to fulfil their expectations for each role. To examine the specific social role that stakeholders endorse for the SAR, we conducted a Two-Step Cluster Analysis within the answers' of stakeholders that concerned only the use of the SARs. In the analysis, nine variables representing the subcategories that resulted from the content analysis were included. These were also related to the social role and the tasks that the robot can perform. The nine variables were the following: "Assistant for students", "Assistant for teachers", "Goal-directed behaviour", "Human-like Personality", "Natural language", "Non-verbal" dialogue", "Daily life Assistance", "Play" and "Learning ICT/STEM". The rest of the subcategories were excluded due to the shallow frequency within participants' answers (their total frequency did not exceed 18% of the total responses), and thus, they could not have meaningful representation in the clustering.

Four clusters were identified, and the overall model quality was found to be good (the average silhouette of cohesion and separation = 0.6). All participants were classified in one of the four clusters. The four clusters are almost equal in size (the ratio of the clusters' sizes was 1.25). Cluster membership was normally distributed among clusters with 26% in Cluster 1 (*n*=33), 24.4% in Cluster 2 (*n*=31), 22% in Cluster 3 (*n*=28) and 27.6% in Cluster 4 (*n*=35). Between the clusters, the most important variables were "Assistant for students" (importance= 1), followed by "Goal-directed behaviour (intentionality)" (importance=0.87) and "Daily life assistance" (importance=0.80). The importance of these variables shows that they are the crucial features, which differentiate the role of the SAR. The least important categories were "Assistant for teachers" (importance=0.15), "Natural Language (Dialogue)" (importance=0.15), and "Nonverbal (Dialogue)" (importance=0.07). The variables with high importance should be seen as those that differentiate the different conceptions of the SAR, while the variables with low importance as equally important variables regardless of how the participants perceive the various SARs.

In the first cluster, the SAR is perceived as an assistant that would facilitate students during the learning process while doing their homework or being their learning pal. Therefore, this role of the SAR is close to the role previous scholars described as "robot teaching assistant" [e.g., 7] or "learning assistant" [e.g., 33] and might be named as an *Assistant for students' learning robot.*

In the second cluster, more than half of the participants (68%) perceived the SAR as an intentional agent that would act as a tutor/mentor who would be able to think, motivate students, increase their interests, and advise them. Hence, this role of the SAR is closed to the role previous scholars described as "Robot as a tutor or as a teacher" [e.g., 5], "a tutor robot" [e.g., 7], or "Robot tutor" [e.g., 33] and might be named as "*Intentional Tutor/Mentor Robot".*

In the third cluster, the stakeholders endorsed the role of the robot as a medium that would be employed to perform tasks related to daily-life assistance and control of various applications. Almost half of the participants in this cluster (53%) endorsed this aspect as necessary to design a SAR. Hence, this role of the SAR is close to the role identified in the literature as "Learning tool" [e.g., 7], or "Learning tool/Teaching aid" [e.g., 32] and might be named as "*Robot for Daily life assistance".*

In the fourth cluster, the stakeholders did not suggest a particular role for the SAR or provided unique wishes with low frequency. Therefore, they were excluded from the analysis. According to this rationale, we named this cluster as "*no particular role for the robot".*

Summing up, the Two-Step Cluster analysis showed that most of the stakeholders (72.4%) suggested three particular roles for the SAR that will be built for education. These roles are close to the roles previous scholars [5, 7, 32, 33, 34] have described as potential roles of the social robots or SARs. The analysis allows the extraction of the cluster membership for each participant for further exploration.

To define the potential combinations of the features the stakeholders perceive for each use of the SAR, a second Two-Step Cluster Analysis was conducted. Eleven variables were inserted in the analysis, namely the cluster membership for the role of the SAR and all the categories that resulted from the content analysis regarding the appearance (i.e., User-Friendly, Embodiment, User Modelling, Personality, Dialogue, and Human-oriented perception) and the voice of the robot (i.e., Human-oriented perception, User modelling, Dialogue and Emotions).

The analysis yielded five clusters with an overall model quality being fair (the average silhouette of cohesion and separation = 0.2). The ratio of the clusters was 1.65. Once again, all participants were classified into one out of the five clusters. Cluster membership was normally distributed among clusters with 21.3% in Cluster 1 (*n*=27), 18.9% in Cluster 2 (*n*=24), 18.1% in Cluster 3 (*n*=23), 26% in Cluster 4 (*n*=33) and 15.7% in Cluster 5 (*n*=20). Among the most important variables of the clusters were the *User Modelling of the voice commands* (importance=1), the *Embodiment* of the robot's appearance (importance=0.78) followed by the *role of the SAR* revealed by the first Two-Step Cluster Analysis (importance =0.60), and *The human-oriented perception* of the voice commands (importance=0.50). Among the least important variables were the *Dialogue* (importance=0.06), the *Emotions* of the voice commands (importance=0.06), the *Personality* of the robot (importance=0.05), the *User Modelling* of the appearance (importance=0.05), and *The human-oriented perception* of the appearance of the robot (importance=0.02).

The first cluster was constructed around the role of the SAR as an "*Intentional Tutor/Mentor*", namely a robot able to think, motivate students, increase their interests, and provide advice. The most important feature (endorsed by all members of the cluster) in this cluster was the *User Modelling* category corresponding to the participants' wish for a dynamic and customisable voice of the robot, which can also adapt its voice to different situations and end-users' needs. At the same time, two-thirds of them preferred a *User-Friendly* and convenient *Appearance* for their SAR; they considered its aesthetics, the construction material, the size and the weight, its functionality or movement to be friendly for the user. So, this cluster might be named the "*Intentional Tutor/Mentor*" robot.

Two clusters, the second and the fifth, were constructed around the role of the SAR as an "*Assistant in learning for students*". The second cluster attracted the participants' wishes for the embodiment of the SAR (varying among zoomorphic, anthropomorphic, non-anthropomorphic, and caricatured appearance) and a *Human-Oriented voice Perception* (it reflects the speech recognition functionality and the various types of perception that the voice could depict). Thus, this cluster might be named "*Assistant for students' learning robot with a human-oriented voice perception and an embodiment type that matters*". The fifth cluster, however, attracted the participants' wishes for a SAR with a human-oriented voice perception and a user-friendly appearance. So, this cluster might be named as "*Assistant in learning robot for students with human-oriented voice perception and user-friendly appearance*". In other words, the analysis showed that the stakeholders hold two alternative conceptions for the SAR regarding the role of "*Assistant in learning for students*". Both emphasize the importance of the human-oriented voice perception for its assistive role. However, one conception connects its role with the SAR's embodiment, while the other with features that refer to its user-friendly appearance.

The third cluster was constructed around those who did not assign any particular role for the SAR employed in educational settings. Nevertheless, half of them converged into the need for a dynamic and customisable voice as an essential feature of the SAR so that it can support end-user's needs. We named this cluster "*No particular role robot with a dynamic voice*".

The fourth cluster attracted wishes for a SAR with the role of the "*Robot for Daily-life assistance*". To serve this role, the SAR is perceived with a human-oriented voice perception. Thus, even if the participants expected the SAR to perform low agency tasks, they perceive the SAR with speech recognition. Therefore, this cluster might be named "*Robot for Daily life assistance with human-oriented voice perception*".

To examine whether the cluster membership depends on the gender of the stakeholders, their country, or their identified category, three Pearson's chi-square tests were applied to the data. The test revealed that the cluster membership depends on the gender of the stakeholders ($x^2(4) = 12.352$, $p=.015$, Cramer's V=.312). Males endorsed more the 1st (63%) and the 4th Cluster (57.6%), while females (85%) endorsed the 5th Cluster. The variable of gender was equally distributed within the 2nd and 3rd Cluster. No other significant difference was found within the variables of the category the stakeholders identified with ($x^2(16) = 19.596$, $p=.239$, Cramer's V=.196), or their country of origin ($x^2(16) = 18.526$, $p=.294$, Cramer's V=.191). Further, to examine whether the cluster membership depends on the level of education that stakeholders were identified with (i.e., primary, lower secondary and upper secondary), the representatives from the STEM companies and the university students were excluded from the analysis. Thus, in the analysis, only the 110 stakeholders (principals, teachers, students, and parents), who classified in one of the clusters, were included. The Pearson's chi-square test showed that the cluster membership does not depend on the level of education they represented, $x^2(8) = 10.240$, $p = .249$, Cramer's V=.249.

4 Discussion

The current study was designed to map stakeholders' requirements for a SAR exploited in a typical class context. A participatory design approach was employed in engaging stakeholders with different affiliations in 15 focus group discussions across five European countries. In each country, three (i.e., one for each level of education; primary, lower secondary and upper secondary education) focus groups were organised, engaging stakeholders such as students, teachers, and school principals as well as parents and STEM companies' representatives. The stakeholders offered their wishes for three topics of a SAR: its role in the class, its appearance, and its voice commands. For each topic, the wishes were grouped into subcategories and categories. The categories are perceived as the different dimensions or variables that connote stakeholders' thoughts about the topic. The subcategories that are included in each category represent the more concrete aspects and might be considered as the properties that the developer should consider within each dimension. Finally, the themes might be seen as the values each dimension might have. Eighteen dimensions with forty-two aspects have been captured in total for the three topics. Most of them were identical to those previous scholars described as the dimensions that the developer of a SAR should consider, and they were included in taxonomies accordingly. This is an indication that the suggested design principles are in alignment with the existed literature. Scholars, however, suggested solutions for the educational robots that are not constrained by the on-board intelligence using the cloud as a part of SAR's brain [46], exploiting mobile devices [66], or using both online and offline social networking sites in their interactions with the users [47], ideas that our stakeholders did not suggest. Nevertheless, the stakeholders suggested additional dimensions like the need for a user-friendly artefact.

The study proposes a set of pivotal design principles for developers that set a generic theoretical framework for what the developers should consider when building a SAR in a specific context. This theoretical framework allows them to specify the dimensions and characteristics that the developers should consider in their effort to develop a SAR for the education, namely as the theoretical framework (Type I theory in terms of Gregor) [67]) that should guide their design. This type of theoretical contributions is valuable when it provides descriptions and analyses of "*what is*" [67]. The principles are the investigation results of an interdisciplinary team of researchers during the "*Fuzzy Front End*", which is the very early phase of a new product design and development [68]. As such, they are not unique solutions for the final design of the particular parts of the SAR. The construction of a SAR demands a theory for design and action (Type V theory in terms of Gregor) [67]. The principles provide the designers with the necessary prescriptive theoretical knowledge to develop SARs for a particular use. At the same time, they allow them for decisions that produce a variety of products. Hence, they can serve as the basis of the theory of design and action. Especially in the product concept design, where "*concepting*" refers to the fundamental outlining of the product, these outlined principles' interpretation will be concretized during the product design process [69].

The study recruited stakeholders from five European countries. Although the countries represent Europe geographically, the stakeholders involved in the study were convenience and voluntary response sample. It is known that transferring an innovative educational idea from one educational context to another demands critical transformation as teachers have different professional profiles [70]. Thus, the pivotal design principles derived from the current study might not be fully applied in other educational settings, and their universality might be moderate. Moreover, some studies showed that cultural background affects the perceptions individuals have for the robots [71, 72]. In addition, scholars have indicated that the designers who implement the design principles for SARs can be subject to cultural and social biases [73]. Despite the variety of stakeholders involved in the study, the only significant difference in the cluster membership was found between males and females. Future studies should involve stakeholders from a larger number of countries for more comprehensive cross-cultural settings to avoid any potential bias or to confirm the applicability of the design principles in other settings too.

4.1 The guiding design principles of a Socially Assistive Robot for Education

Previous studies are limited in terms of creating lists of features that the stakeholders wish for the SAR. Although these lists are helpful for the developers, they do not provide an idea on how to combine the features to build a SAR that will meet the stakeholders' requirements. The content analysis and the Two-Step Cluster Analysis underlined four general and six specific guiding principles regarding the features of five robots with distinct social roles that might be exploited in a typical class context. Thus, the current study provides the developers with a set of general and specific *guiding design principles* for developing a SAR to be used in educational settings and a typical class. Table 2 summarises the general and the specific guiding principles for each of the different robots that could be developed according to stakeholders' requirements for education.

Table 2: The Guiding Design Principles for designers aiming at the design of a SAR exploited in education

Guiding Design Principles	Explanation
General Design Principles	
1. Design for a specific context	Designers should consider the specific context the robot will address.
2. Consider user's needs	Designers should consider the specific users' needs.
3. Personalise the design acknowledging diversity and difference	Designers should allow the adaptation of the robot's system to the users' needs and wishes, acknowledging the diversity and differences among the users.
4. Account for the risks of HRI	Designers should consider the risks that might result from HRI and prevent the adverse effects on humans or the educational system.
Specific Design Principles	
1. Develop communication systems exploiting a dialogic mode and natural language	Designers should establish a communication system to the robot allowing humans to interact with robots naturally through natural language.
2. Develop voice commands reflecting emotions and emotional intonations	Designers should develop voice commands that reflect human emotions and emotional intonations, which could facilitate the human-robot communication, and render the robots as empathic and social agents.
3. Include a speech recognition functionality for the robot	Designers should integrate a speech recognition functionality to the robots, allowing recognition and correspondence to the human voice similar to human-human interaction and communication.
4. Allow customisation of the robot's appearance for the user	Designers should allow some adaptations of the appearance of the robot to the users according to their wishes and preferences.
5. Focus on the personality of the robot	Designers should design a specific coherent personality for the robot that users can recognise and enjoy in the HRI considering the possible threats.
6. Decide on the social role of the robot	Designers should consider assigning a particular social role(s) to a robot for a particular context and use.

4.1.1 General design principles of a Socially Assistive Robot for Education

General Design Principle 1: Design for a specific context

According to this principle, designers should consider the specific context the robot will address. The content analysis results revealed that as a specific context, we could perceive the learning environment, the subject matter, the field of the robot's exploitations or the task it will perform. Moreover, an instructional approach or addressing learning for conceptual or procedural knowledge also affects the context of the robot's application. To illustrate, a robot employed to support the inquiry learning approach could have personality features that support hypothesis testing or inference [74]. In contrast, a robot employed to facilitate teacher-based instruction could have characteristics and hardware features that support the presentation of educational materials (e.g., display video). Finally, designers should consider that among the context specificities, users are also included. Notably, this means that a robot designed for exploitation in the specific context of special education should consider and correspond to the distinct characteristics that these students might have [75].

General Design Principle 2: Consider users' needs

This principle was evident by the content analysis, and it highlights that the designers should consider the users' specific needs. The current results underlined that each group of stakeholders engaged in the study expressed various needs and wishes. Additionally, the Two-Step Cluster Analysis revealed that from the users' demographical characteristics, gender was an important factor rendering different preferences regarding the design of the robot. To develop valuable and exploitable robots, developers need to understand users' needs and represent them in precise requirements. The process of representing the users' needs to technical requirements is challenging, and some scholars have developed methodological approaches [e.g., 76] claiming to bridge the gap between designers and end-users. Thus, the designers' work regarding the extraction of the technical requirements from users' needs is facilitated.

General Design Principle 3: Personalise the design acknowledging diversity and difference

The personalisation principle [77] is one of the most prominent design principles in multimedia learning. According to this principle, designers should allow the adaptation of the robot's system to the users' needs and wishes. Moreover, by providing personalisation opportunities, designers should acknowledge the diversity and differences among the users. Therefore, a variety of options per feature should be considered. For instance, the content analysis revealed that the users wished for the robot's appearance to be personalised through colours. Considering this, designers could investigate further whether younger or older students prefer different colours for the appearance of the robot. Similar wishes were expressed concerning the robot's voice commands, which should be able to change according to the users' gender, nationality, or age. This principle highlights that products are designed to tailor content for a different set of users based on their needs, demands and use. Finally, the Two-Step Cluster Analysis highlighted the importance of this general design principle, as gender-related differences were evident in the types of robots that emerged. Recent experiments align with this principle. They showed the importance of the personal needs and the gender of the users to favorite (or not) the personalized with clothes robots in a telepresence setting [78].

General Design Principle 4: Account for the risks of HRI

Designers should be aware of the risks that might result from HRI, investigate them more deeply, and prevent through their designs their adverse effects on humans or education through the exploitation of robots. Specifically, the current content analysis revealed that stakeholders worry about potential risks that could result in humans after their interaction with robots. Although a few scholars have reported claims about potential risks resulting from HRI [79, 80, 81, 82], future research should investigate their effects with experimental designs. Additionally, designers, when including stakeholders and users in the design, should be informed about the ethically driven methodologies for the design of Robots [e.g., 32, 83]. Thus, the acceptance of robots in education would be facilitated and not jeopardised.

4.1.2 Specific design principles of a Socially Assistive Robot for Education

The Two-Step Cluster Analysis revealed that some features have an equal chance to be wished across the five SARs that emerged. Therefore, they are not those in the limelight in differentiating the role and the use of the SAR in the class. The integration of these features in the design of a SAR for education is advisable. Thus, we consider them as specific design principles for educational SARs. Six specific design principles are identified from the analyses. The most critical specific design principle is related to the robot's social role, as it can specify even further the design of an educational SAR.

Specific Design Principle 1: Develop communication systems exploiting a dialogic mode and natural language

Developers should establish a communication system exploiting dialogue and natural language to the robot [84]. For humans, language is the most readily accessible means of communication. Thus, a communication mode as such would allow humans to interact with robots naturally. Besides, the dialogic communication mode would facilitate HRI in dynamic and complex environments, such as educational settings. As the content analysis indicated, the natural language should be auto-corrected, keep a record of the previous communications with a user, and continue the communication from the point that stopped the last session. Additionally, it should adopt other human characteristics, like engaging (or not) in verbal communications, speaking gradually, or answering questions, among others.

Specific Design Principle 2: Develop voice commands reflecting emotions and emotional intonations

According to this principle, designers should develop voice commands that reflect human emotions and emotional intonations, facilitating the human-robot affective dialogue [85, 86] and communication. At the same time, adding such qualities to the communication systems of the robot might render them empathic agents capable of understanding the emotional state of others [87]. Further, this principle highlights that stakeholders wish for robots, which have characteristics of social agents. The content analysis indicated that if designers wished to develop voice commands that reflect emotions, these should be expressed in a neutral tone, be funny or polite, but not monotonous. Finally, accepting positive feedback and communicating in a positive tone is also desirable for stakeholders.

Specific Design Principle 3: Include a speech recognition functionality for the robot

This principle requires developers to integrate a speech recognition functionality to the robots to recognise and correspond to the human voice [84]. Additionally, it underlines the importance of developing robots with social characteristics akin to those exhibited by human agents in human-human interaction and communication [see also 88]. The content analysis revealed that stakeholders wish this speech recognition feature to allow the robot to understand and follow the human voice commands.

Specific Design Principle 4: Allow customisation of the robot's appearance for the user

In line with this design principle, developers should design the robot's appearance so that the users could make adaptations according to their wishes, needs and preferences [89, 78]. In contrast to the general design principle of personalisation, customisation places the user's impetus for change. For instance, the designers could facilitate the robot's customisation if they employ a material for the construction of the robot, which could allow the users to paint and colour it as they wish. Thus, the user is the one tailoring the appearance of the robot. The content analysis revealed that the users should modify the robot's appearance, which should be improved by adds-on and gadgets or adapted to facilitate emotional attachment.

Specific Design Principle 5: Focus on the personality of the robot

The following principle is rendered as essential from the Two-Step Cluster Analysis. It refers to the integration of another social feature to the robot. Specifically, this principle stresses to developers that they should design a specific personality for the robot. Robots can manifest personality traits, which users, in return, can recognise and enjoy in the HRI, mainly when they are in line with their own [90]. The current content analysis provides developers with ideas on designing a robot similar to mobiles, tablets, and robots presented in books and movies, or even unlike a machine-like robot. Finally, the personality attributed to a robot could be closely related to the robots' social role.

Specific Design Principle 6: Decide the social role of the robot

According to this principle, designers should decide and assign a social role to a robot. A social role could be related to all the behaviours, capabilities, hardware, or software features, as well as the level of autonomy exhibited by the robot in a social situation. Thus, the designers' social role will attribute to the robot defines the most prominent characteristics that would be developed for the robots. Literature has highlighted many potential social roles that a robot could display in education [e.g., 5, 31]. The data analysis methods employed in the current study and expressly, the Two-Step Cluster Analysis indicated three distinct social roles for a robot employed in education.

The intentional *Mentor/Tutor* is the SAR with high-level cognitive skills allowing the SAR to think, motivate students, increase their interests, and advise them. This role of the SAR resembles the more advanced assistive role for the SAR that demands a high level of agency and previous scholars described as "Robot as a tutor or as a teacher" [e.g., 5], "a tutor robot" [e.g., 7], or "Robot tutor" [e.g., 33]. The second SAR sketched in the study is the SAR that will serve as an *Assistant of students in learning*. The SAR for learning assistance involves general duties that it can undertake in the class, such as assisting students in homework or learning pal. This double role of the robot resembles the roles scholars have suggested for the SAR employed in educational settings. For instance, scholars suggested that the SAR in education might serve as a peer, companion, or co-learner [5, 7, 31, 33]. The third social role of the robot was determined by the expected task that could be assigned to it. Among various tasks that the stakeholders wished for, the task of the *Daily-life Assistant* was the most prominent. Further, the results suggested that a significant percentage of stakeholders did not endorse any of the above roles for the SAR, suggesting unique uses and role for it.

Surprisingly, further analysis revealed that according to the social role of the robot, the design features of the robot are further specified. Thus, as soon as designers decide on the social role a robot for education could have, they should consider the following more specific design features. For the *Mentor/Tutor* type of robot, designers should integrate a user-friendly appearance considering the size and weight, the movement, the aesthetic aspect, the properties of the material that the robot will be constructed, or its overall functionality. Additionally, they should integrate a dynamic voice for the robot, which could be customized by the end-user's preferences. Combining these features with an advanced – in agency – social role of a robot as a mentor or tutor, one can argue that stakeholders wished for an intentional social agent, used for advanced learning topics such as self-regulation [91] or critical thinking dispositions [92].

For the "*Assistant of students in learning"* social role, designers should consider including additional features such as the speech recognition function and filtering the voice commands to avoid any devious use during HRI. Moreover, for this particular role, two subgroups of additional features emerged from the analysis. For the first, the stakeholders suggested the embodiment as a vital dimension the designers should consider. Three types of embodiment for the SAR might reflect the anthropomorphic, the zoomorphic, the caricatured. At the same time, stakeholders wished for a robot design, which avoids a real human-like body. Mainly females endorsed the second subtype of the SAR that will serve as an assistant of students in learning. The critical dimension that the designer should consider is for it to be user-friendly in appearance. This dimension includes features that are closer to those the stakeholders wished for the *Mentor/Tutor* SAR. Therefore, one could suggest that this type of robot might be an advanced version of the *Assistant in Learning SAR* and the precursor of the *Mentor/Tutor*.

For the *Daily-life Assistant*, stakeholders (mainly the males) wished for the robot to have a human-oriented perception in its voice and mainly to be able to understand human speech and to communicate with them.

Finally, for the robot that no particular social role was assigned, stakeholders wished to have a dynamic voice that the users could customise according to their gender, age, or nationality.

4.1.3 The validity of the Design Principles

In the current study, stakeholders were engaged at the very beginning of the PDA steps, namely the phase of needs analysis and requirements gathering [11]. The data analyses allowed us to group the requirements into general and specific design principles. For each of these principles, we have presented evidence showing their *construct validity*, namely that they correspond to the existed theory or practice in the field of Socially Assistive Robotics. These principles, however, are abstractions of what the stakeholders said, and they might not be accurate and corresponding to the stakeholders' expressed wishes. To test the *validity* (i.e., the principles we have formulated correspond to the stakeholders' genuine wishes and thus, they measure what they are supposed to measure) and the *reliability* (i.e., whether these principles can be acknowledged and reproduced by another group of stakeholders under the same conditions) of these principles [93], we invited the stakeholders to participate in focus group discussions to scrutinize the output of the data collection procedure [94], that is the principles we formulated based on their wishes. By carrying out continuous member checking with stakeholders during the various stages of the PDA (e.g., requirements gathering, concept design, prototyping, testing), it is expecting that transactional validity can also be achieved [93]. Specifically, 15 member checking sessions were carried out in the five European countries (i.e., three for each country and one for each level of education; primary, lower secondary and upper secondary education) with 137 stakeholders (students, teachers, school principals as well as parents and STEM companies' representatives) participating in total. These member checking sessions helped us ensure the *validity* and *reliability* of our study before being used by the developers. Almost half (49%) of the participants of the member checking sessions had also participated in the focus group discussion from which the original data resulted. The stakeholders who had participated in the first focus groups confirmed that the extracted principles correspond to what they had in mind when they expressed their wishes, covering all aspects of their wishes (i.e., the *internal validity*). The stakeholders, who participated for the first time in the second focus groups, expressed wishes that could correspond to the extracted principles, indicating that these principles will be replicated if the study will be done again (i.e., the reliability of the study) and, hence, they could be generalised at least for the five European countries. However, the developers should be cautious when they decide to use these principles without prior testing outside the European educational settings.

Although it is outside of the current study's scope, in our knowledge, the design principles have also been used to shape a theory of designing an innovative SAR for education [95]. Following the traditional approach within the design science research [96], the developers built a prototype SAR for educational settings. They designed a case study to evaluate the effect of the SAR in the class real-world settings [97]. In particular, they presented the student's evaluation of the SAR's appearance and non-verbal behaviour during a robot-assisted collaborative lesson addressing a STEM topic. Students evaluated the innovative SAR very positively and much higher than the chance level [98].

4.2 Conclusion

The current study is the first to employ a participatory design engaging diverse groups of educational stakeholders such as students of various age groups, teachers of various educational levels, school principals, parents, and experts from the market sector coming from five European countries. Additionally, it underlines the importance of stakeholders' involvement in the design of a SAR. Specifically, the current study provided five types of robots that the design of a SAR for education could implement to meet the needs and requirements suggested by the stakeholders. Besides the different analyses employed in the current study, four general and six specific and valid *pivotal design principles* for the developers interested in designing a SAR to be used in a typical class setting were suggested. Further, the study contributes to the educational robot design research as it provides a holistic overview of features that developers should consider for the design of an educational SAR while firstly underlining its social role. Finally, the insights gained from the current study highlight that developers should consider different combinations of features for the SAR design to correspond to the particular groups of stakeholders' needs.

Compliance with Ethical Standards

All procedures performed in studies involving human participants were in accordance with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent

Informed consent was obtained from all individual participants included in the study.

Conflict of Interest

The authors declare that they have no conflict of interest.

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6 Appendices

Appendix 1: The subcategories and categories emerged from participants’ wishes regarding the assisting role of the SAR in the class. Stakeholders’ endorsements are presented in reference to the subcategories.

Categories	Subcategories	Stakeholders’ endorsements per subcategory	Key themes	Indicative quotes
The role (assistant in learning) of the SAR [22]	Assistant for students [31]	Principals Teachers Parents Students	assist the educational/learning process	to assist the educational process
			learning pal	buddy learning
			assist students in homework	to assist students with their homework, so that they won’t be bored
	Assistant for teachers [7]	Teachers Students Parents	the robot to support teachers	To assist teachers
Task expected by the SAR [22]	Daily life Assistance [22]	Teachers Students Parents Principals STEM companies’ representatives	the robot to facilitate everyday life	Sorting garbage bags, cleaning empty jars, and driving independently to the glass container
			the robots to be used to control the applications	Robots should be able to control a wide range of apps, like the timer
	Play	Students Teachers Parents STEM companies’ representatives	use robots to play	The robot could also be used for play
			learning through playing with the robots	Learning by playing, that is, it is a means to have fun with him, but it helps me to want to learn.
			use the robot as an educational game	it is possible to play with it
	Learning ICT/STEM	Parents	use the robot to learn in ICT/STEM courses	program possibly created projects (e.g. as programs in computer science) at him and try him
	Tool	Teachers	use the robot as a tool for learning	can be used as a learning object

		Students Parents STEM companies' representatives	use the robot as a device or application	We could also use it for everyday things like mobile
	Learning	Teachers Students Parents Principals	learning by teaching the robot	the robot can be "taught" to self-learn
			use the robot as a search engine	source of information
	Fun	Teachers Students	use to have fun with the robot	to have fun in the classroom
	Multidisciplinary Learning	Students	use the robot in many different subjects	in a diverse range of subjects
	Skills Learning	Principals	use the robot to learn transversal skills	to strengthen the ability of logical thinking
	Problem-based learning	STEM companies' representative	use the robot for problem-based learning with students	Problem-teaching situations
The intentionality of the SAR [20]	Goal-directed behaviour [20]	Teachers Students Parents Principals STEM companies' representatives	motivate students	to inspire and motivate children
			the robot to be able to think	To be able to think about what to do
			raise users' interests	increase the young learner's interest
			the robot to advise	advising and teaching alongside
			the robot to be a teacher/mentor/tutor	it is a robot mentor, it can teach
Personality [20]	Human-like personality [20]	Teachers Students Parents Principals STEM companies' representatives	friendly robot	to look like […], friendly
			the robot to has a personality	with personality
			the robot to reward students	to […] when you have done something well, you get sweets
			the robot to be like a friend for the user	but it should be as a kind of "friend"
			the robot to be nice	to be nice
			the robot to help with problems	help with problem

Dialogue [20]	Natural language [20]	Teachers Students	the robot to provide feedback	to provide feedback
			the robot able to discuss	so it can have a conversation with you
	Non-verbal [20]	Students	the robot to express emotions	to express emotions
User population [20]	*Users in Group*	Teachers Students STEM companies' representatives	group (students) use of the robot	to be used in teams
	Individual Users	Teachers Students	individual (student) use of the robot	use the robots in the classroom individually
Field example	*Work*	STEM companies' representatives Students	use the robot at work	be used in education, at work, and to those who are alone
	Education		use the robot in education	be used in education, at work, and to those who are alone
	Special Education		use robots in special education	to be used more with special kids
	Care		use the robot for people's care	be used in education, at work, and to those who are alone
Risks emerging from using robots	*Risks from using SARs*	Students	use the robot without replacing humans	use less in our daily lives so as no one loses their job
			the robot not to replace people	not to replace people

Note: Italicized shows the inductively generated categories and subcategories.

Appendix 2: Categories and Subcategories that emerged for the question of what the SAR would look like. Stakeholders' endorsements are presented in reference to the subcategories.

Categories	**Subcategories**	**Stakeholders' endorsements per subcategory**	**Key Themes**	**Indicative quotes**
User-friendly	*Size and weight of the SAR*	Students Principals STEM companies' representatives	medium size of the robot	medium-sized
			small size of the robot	Small. So that you can put the robot into your school bag
			big size of the robot	Large
			the robot to be lightweight	Lightweight and small
	Movement	Students Parents Teachers Principals	portable robot	easily transferred
			the robot to be able to move	Be able to move
	Aesthetics of the SAR	Students Teachers	neutral appearance	neutral appearance
			natural design	look as natural as possible
			the robot to be attractive	Be attractive
			the robot to be nice	The robot to be nice
			minimal design	Scandinavian style, that is, simple lines
			the robot not to be scary	Interesting and not intimidating that everyone will like
			modern design	Simple, modern
	Material for the construction of the SAR	Students Parents STEM companies' representatives	the robot not to be made by iron	not iron
			water-resistant	The robot should be water-resistant, mechanically durable and manufactured with the environment in mind
			fall/hit resistant	The robot should be water-resistant, mechanically durable and manufactured with the environment in mind

			the robot to be from soft material	It should be soft
			the robot to be made by iron/metal	metal
			environmentally friendly construct	The robot should be water-resistant, mechanically durable and manufactured with the environment in mind
	Functionality of the SAR	Students Parents	the robot to be easy to use	Easier to use
			the robot to be able to charge	charging
			the robot to be foldable	Like an origami paper swan. Foldable
Embodiment [20]	Anthropomorphic [20]	Teachers Students Parents Principals STEM companies' representatives	human-like robot	More humane
	Non-anthropomorphic being	Students Parents Principals	not human-like robot	no human-like
	Zoomorphic [20]	Students Principals	animal-like robot	And in appearance, I think it should be a robot that has a pet-like appearance
	Caricatured [20]	Teachers Principals STEM companies' representatives	similar to cartoons	like a cartoon character
User modelling [20]	Dynamic [20]	Teachers Students Parents Principals STEM companies' representnatives	the robot to be similar to the user to achieve attachment with the user	should they somehow can make yourself, so you have a better bond with him.
			customisable robot	the choice of colour, everything can be customised on request

Personality [20]	Tool-like [20]	Teachers Students Parents Principals STEM companies’ representatives	the robot to be like a mobile phone/tablet	as a tablet
			the robot to have games	With games for younger children, with gadgets for older
			the robot to be multifunctional	multifunctional
			the robot to have gadgets	With games for younger children, with gadgets for older
			the robot to have applications	he should have WhatsApp
	Artificial being [20]	Teachers Students Parents STEM companies’ representatives	the robot to be a hologram	hologram, showing on a projector, video
			machine-like robot	like a typical robot as known in from the books/movies
	Non-artificial being	Students	not machine-like robot	I do not want the robots to be droids
Dialogue [20]	Natural language [20]	Students	text to speech and speech to text ability of the robot	To write something and it reads your text
Human-oriented perception [20]	Speech recognition [20]	Students	the robot to understand voice commands	the robot can understand voice commands

Note: Italicised shows the inductively generated categories and subcategories.

Appendix 3: The categories and subcategories related to participants' wishes regarding the voice commands of the SAR. Stakeholders' endorsements are presented in reference to the subcategories.

Categories	**Subcategories**	**Stakeholders' endorsements per subcategory**	**Key Themes**	**Indicative quotes**
Human-oriented perception [20]	Speech recognition [20]	Teachers Students Parents Principals STEM companies' representatives	understand robot's voice commands easily	to be easily understood
			clear voice commands	They are clear
			easy to use voice commands of the robot	in order to guarantee an easy use
			easy to control voice commands	should be controlled, for example, simple commands instead of more complex conversation activities (thereby avoiding any commotion, playing and chaos in class)
			voice commands that function	They are much more efficient
			voice of the robot to sound like the human voice	Resemble the human voice
			voice commands to be like one of existing voice commands systems	Siri style Apple
			voice commands to be a remote control	a remote control
			voice commands to control all functions of the robot	voice commands to control all the functions of the robot
			control mode of the robot	Voice commands would be part of the control method
			voice commands to control the most critical functions of the robot	the most necessary functions, for example. To send outputs, the actual image
			voice commands to do what the user asks for	He's supposed to do what I say
			control the robot verbally	Verbally control the robot
			the user to program the voice commands	user-programmable

			control voice commands by text	to control the voice also commands by the text
	Types of perception [20]	Students Parents	filter malicious voice commands	but have a filter for orders and commands so that they will not be used as a toy
			voice commands to be used cautiously	I wish the voice commands of the robot to be used cautiously so that no damage occurs
			the robot to obey only the voice of one man	it could be sound sensing that it would obey only the voice of one man
User modelling [20]	Dynamic [20]	Teachers Students Parents Principals STEM companies' representatives	customisable voice commands	can be changed (male, female voice, a student can do it, etc.)
			robot voice to be like the user's voice	can be customised to each person
			choose the voice of the robot	can choose the voice of the robot
			robot to have many different voices	to have as many voices as they want
			robot voice to be of the people the user admires	The voice of a person you admire (Einstein)
			voice commands in users' native language	in everyone's language and in one more language so as to give knowledge and make lessons interesting
			Choose the language of the robot's voice commands	Choosing the language you want
			voice commands operate with many languages	to work in multiple languages
			voice of the robot according to age	Resemble the human voice, which can be adjusted according to age
			voice of the robot according to gender	can be changed (male, female voice, a student can do it, etc.)
Dialogue [20]	Natural language [20]	Students	voice commands to give the "good example" to students	it could teach good habits

		Teachers Parents STEM companies’ representatives	voice commands to have an auto-correction system	to make corrections, after check
			voice commands to continue form previous sessions	have continued from previous sessions
			voice commands to use existing knowledge	interact on existing knowledge
			give voice commands gradually	provided gradually
			voice commands to turn on/off	it would be possible to introduce or turned off.
			voice commands to facilitate Human-Robot Interaction	Help interact with us
			voice commands to answer users’ questions by voice	to be able to answer my questions by voice
			voice commands to facilitate translation in STEM-related texts	use to translate relevant to STEM texts
			voice commands to test students’ knowledge	tests the student’s knowledge
Emotions [20]	Speech [20]	Students Principals STEM companies’ representatives	not monotonous voice commands	would not be monotonous
			voice commands to be in a neutral tone	sound like a neutral tone
			voice commands to convey emotions	the voice commands to convey emotions
			funny voice commands	The voice commands would be funny
			voice commands to be polite	it would be polite and civilised
			voice commands to accept positive tone commands/positive feedback	Much warmer voice commands

Note: Italicised shows the inductively generated categories and subcategories.