Second Language Tutoring using Social Robots

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L2TOR

Second Language Tutoring using Social Robots

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Dissemination Level		
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PP	Restricted to other programme participants (including the Commission Service)	
RE	Restricted to a group specified by the consortium (including the Commission Service)	
CO	Confidential, only for members of the consortium (including the Commission Service)	

Contents

Executive Summary

Ethical considerations are central to practically all development in robotics and Artificial Intelligence. L2TOR committed to engage with a discussion on the ethics of using robots in tutoring scenarios with children. This document captures that discussion and lists the guidelines we commit to as a consortium.

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Revision History

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First and final version.

Version 2.0 (TB 16/10/2017)
Revised version in response to the recommendations received after the Period 1 review meeting.

1 Introduction

In the research proposal we suggested to use an External Ethics Advisor (Prof Alan Winfield) to advise the project on ethical considerations. Due to professional commitments Prof Winfield was unavailable to meet with the consortium. As an alternative the consortium organised a discussion event at the L2TOR consortium meeting of 27 September 2016 in Oostende, during which the just released British Standard 8611 on "Robots and robotic devices: Guide to the ethical design and application of robots and robotic systems" was extensively discussed and accepted as an ethical guiding framework for the project.

2 British Standard 8611

British Standard 8611 on "Robots and robotic devices: Guide to the ethical design and application of robots and robotic systems" is the only standard on ethical hazards when interacting with robotics and AI systems. From the Scope section:

"This British Standard gives guidance on the identification of potential ethical harm and provides guidelines on safe design, protective measures and information for the design and application of robots. It builds on existing safety requirements for different types of robots; industrial, personal care and medical.

This British Standard describes ethical hazards associated with the use of robots and provides guidance to eliminate or reduce the risks associated with these ethical hazards. Significant ethical hazards are presented and guidance given on how they are to be dealt with for various robot applications.

Ethical hazards are broader than physical hazards. Most physical hazards have associated psychological hazards due to fear and stress. Thus, physical hazards imply ethical hazards and safety design features are part of ethical design. Safety elements are covered by safety standards; this British Standard is concerned with ethical elements.

This British Standard is intended for use by designers and managers, amongst others."
(BS8611, p. 5)

3 L2TOR's ethical framework

While L2TOR adheres to the ethical guidelines imposed by the partner's local institutions, there is a need to adopt a wider ethical framework for practice and systems developed in L2TOR. The consortium agreed to adopt BS8611 as a guiding framework for the project, and specifically welcomes the attention BS8611 gives to ethical hazards (and mitigating actions) in the context of vulnerable persons, including children.

There is a concern that society is not receptive to artificial intelligence, robotics and a number of potential applications of artificial intelligence. This is on the one hand evident in media headlines, and high profile figures such as Elon Musk and Bill Gates warning for negative consequences (and much worse) of AI, but also knows an evidence base in the Eurobarometer of 2012 (see figure 1). In this, a survey is reported in which the public of the 27 EU member states were asked in which application areas robots would be welcomed and where they should be avoided. For education, the domain relevant to L2TOR, only 3% of respondents felt that this should be a priority for robotics, and 34% felt robots should be banned from education, only topped by care for children, elderly and disabled. While the survey is in many ways flawed (for example, the questions were poorly contextualised), the result is cause for concern for L2TOR and for the field of robots for learning in general.

EU27	QA6 In which areas do you think that robots should be used as a priority?	QA7 And on the other hand, in which areas do you think that the use of robots should be banned?	**Areas of robots usage index (Q6-Q7)**
Space exploration	52%	1%	**+51**
Manufacturing	50%	4%	**+46**
Search and rescue	41%	3%	**+38**
Military and security	41%	7%	**+34**
Domestic use, such as cleaning	13%	8%	**+5**
Agriculture	11%	6%	**+5**
Transport\ Logistics	11%	6%	**+5**
Healthcare	22%	27%	**-5**
Leisure	3%	20%	**-17**
Education	3%	34%	**-31**
Care of children, elderly, and the disabled	4%	60%	**-56**

Figure 1: highlight from the Eurobarometer 382, which measured public attitudes towards robots in 2012. From http://ec.europa.eu/public_opinion/archives/ebs/ebs_382_sum_en.pdf

In response to the Eurobarometer study, Plymouth University conducted its own study in 2016 in which teachers and the public were surveyed with regards to their attitudes to robots in the classroom. As literature suggests that teacher attitudes are a strong predictor of technology use in classrooms, so willingness to engage with social robots will influence application in practice. Plymouth's rigorously-framed survey was used to gather the views of both the general public and education professionals towards the use of robots in schools. Overall, they found that the attitude towards social robots in schools is cautious, but potentially accepting. The resulting paper discusses the reported set of perceived obstacles for the broader adoption of robots in the classroom in this context. Interestingly, concerns about appropriate social skills for the robots dominate over practical and ethical concerns, suggesting that this should remain a focus for child-robot interaction research (Kennedy et al., 2016; added as appendix to this document).

The L2TOR efforts (technical development, evaluation in ecologically valid settings, and industrial and societal engagement) need to happen within the framework of BS8611. The following table captures which elements of BS8611 are relevant to L2TOR and how the guidelines are adopted, and where appropriate, implemented in L2TOR.

Table 1: Ethical issues, hazards and risks relevant to L2TOR and to social robots in education in general. The first four columns are from the BS8611 document, the last column provides a comment by the L2TOR consortium.

Ethical issue	Hazard	Risk	Mitigation	Comment by L2TOR
Societal	Loss of trust	Robot no longer used or misused, abused	Design to ensure reliability in behaviour	The validation setup developed in L2TOR needs extensive testing, so it works reliably and predictably in “wild” settings. Several pilots and stress tests will be needed.
	Deception (intentional or unintentional)	Confusion, unintended (perhaps delayed) consequences, eventual loss of trust	Avoid deception due to the behaviour and/or appearance of the robot and ensure transparency of robotic nature	This concern is mainly about “android” robots, which present themselves as being human. The robot adopted in L2TOR is clearly a robot, and as such this concern is of little relevance.
	Anthropo-morphisation	Misinterpretation	Avoid unnecessary anthropo-morphisation Clarification of intent to simulate human or not, or intended or expected behaviour	Anthropomorphisation will be used to some extent in L2TOR in how the robot is presented to the young learner: as the robot is humanoid in nature, the learner will to some extent anthropomorphise. We do not expect negative consequences (based mainly on prior experience of partners).
	Privacy and confidentiality	Unauthorised access,	Clarity of function	Our ethical framework (and the prevailing local

		collection and/or distribution of data, e.g. coming into the public domain or to unauthorised, unwarranted entities	Control of data, justification of data collection and distribution Ensure user awareness of data management and obtain informed consent in appropriate contexts	ethics guidelines) cover the case where robots are used in evaluation settings. When robot tutors are commercial products, there are some genuine concerns. Some of which are covered by European data protection guidelines and legislation, but there remain grey areas.
	Lack of respect for cultural diversity and pluralism	Loss of trust in the device, embarrassment, shame, offence	Awareness of cultural norms incorporated into programming	This is of concern in L2TOR when working with migrant communities. It is unclear where this might manifest itself, so we should be aware of our software or the robot's behaviour being suboptimal in certain cultural context. For example, face detection might work differently when dealing with darker skin colours.
Commercial/ financial	Employment issues	Job replacement, job change, unemployment loss of tax revenue	Appropriate support networks, appropriate taxation, retraining opportunities	In L2TOR we do not envisage to replace teachers (if this at all would be possible), but instead present the robot as an additional learning technology with no consequences for employment.
	Equality of access	Propagation of the "digital divide", isolation of minorities, non-compliance with human rights legislation	Inclusive design of robot behaviour to conform with Corporate Social Responsibility, and recognition of characteristics of intended	While not an issue in the project, there is a concern that robot technology might be expensive and therefore only accessible to the more well-off schools. Mass production should mitigate this somewhat. The consortium agreed that this is a concern of

			application domain Support networks to minimise risks	all new technology, and the L2TOR consortium has little control over this at this stage of the technology development chain.

The L2TOR consortium agreed to accept all the BS8611 General societal ethical guidelines:

a) robots should not be designed solely or primarily to kill or harm humans;
b) humans, not robots, are the responsible agents;
c) it should be possible to find out who is responsible for any robot and its behaviour;
d) robots as products should be designed to be safe, secure and fit for purpose, as other products;
e) robots as manufactured artefacts should not be designed to be deceptive and likely to cause ethical harm;
f) observe the Precautionary Principle;
g) privacy by design;
h) robots able to learn can distance themselves from the intentions of their designers and operators;
i) potential users should not be discriminated against or forced to acquire and use a robot.

(from BS8611)

Conclusion

While the consortium has extensive experience in using social robots with neurotypical and disabled children, we find that promoting awareness of ethical issues within the consortium and society at large is important. We also engage externally with national and EU legislators, notably by being involved in the European Parliament initiative on Civil Law for Robots, in the context of which L2TOR coordinator Prof Tony Belpaeme gave a keynote in the European Parliament and where partner QBMT has received the initiative's lead, Mrs Maddy Delvaux MEP, for a site visit to their offices to introduce her to the commercial activities around social robots.

There are still unanswered questions: we do not know if the technology we develop will work across all people. For example, the technology might not work the same for Caucasian children as for children with darker skin colours. However, by being aware of these and other issues, we aim to have mitigations actions in place.

Finally, our communication to the media should be clear and devoid of hyperbole. Early in the project, some media reported on our efforts in a manner which did not reflect our work accurately. While we had little to no control over how the media reported on this occasion, we should be aware of the potential for runaway media coverage and should try and curb expectations and over interpretation by the press.

References

Kennedy, J., Lemaignan, S., & Belpaeme, T. (2016). The cautious attitude of teachers towards social robots in schools. In *Robots 4 Learning Workshop at IEEE RO-MAN 2016*.

The Cautious Attitude of Teachers Towards Social Robots in Schools

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***Abstract*—Social robots are increasingly being applied in educational environments such as schools. It is important to understand the views of the general public as social acceptance will likely play a role in the adoption of such technology. Other literature suggests that teacher attitudes are a strong predictor of technology use in classrooms, so willingness to engage with social robots will influence application in practice. In this paper we present the results of a rigorously-framed survey used to gather the views of both the general public and education professionals towards the use of robots in schools. Overall, we find that the attitude towards social robots in schools is cautious, but potentially accepting. We discuss the reported set of perceived obstacles for the broader adoption of robots in the classroom in this context. Interestingly, concerns about appropriate social skills for the robots dominate over practical and ethical concerns, suggesting that this should remain a focus for child-robot interaction research.**

I. Introduction

Research involving social robots in educational settings is becoming increasingly prevalent, particularly with children [1], [2]. Indeed, researchers in established fields applied to the educational domain, but using different technologies, have started to call for a switch to developing and evaluating social robots [3]. Work conducted within the field of Human-Robot Interaction (HRI) is taking place over longer-term time-scales as well, inspired by early success stories such as [4], and striving for increasingly sustained real-world application.

It has been shown that robots can be used to successfully teach children, and also offer unique learning experiences. For example, children can teach a less-able peer (in the form of a robot), which may not otherwise have been possible [5], [6]. However, they can also have an impact on the classroom, both in terms of the child behaviour and teacher behaviour [7] (which is also related to the broader concept of technology-mediated *classroom orchestration* [8]).

As this field of research pushes forwards, and if we seek further real-world or mass-market implementation in schools, it is important to understand attitudes towards the technology. For successful adoption of such technologies, it is necessary for both teachers and the general public to be willing participants in increased uptake. Recent findings from the Eurobarometer report [9] have suggested that whilst there is generally a positive view towards robots in Europe, there is a sizeable contingent (34%) that would see robots banned from use in education. However, the survey administered in this report does not provide a context for many of the questions.

In this paper we seek to explore whether, when provided a minimal context, the attitudes of the general public are in fact more positive. We explore the impact of this context on the responses by manipulating an 'imagined' picture of how a classroom with a robot might look (by including a human teacher or not). Using the same survey design we also seek to establish views of teachers (for whom there will be a greater direct impact) regarding the use of social robots in education. Furthermore, the views of teachers about obstacles to the use of robots are considered for insight into possible child-robot interaction research directions.

II. Related Work

Research has suggested that there are barriers to adoption and use of technology by teachers. These can be first-order (extrinsic) barriers, or second-order (personal) barriers. While the extrinsic barriers cannot be discounted, it has been found that positive beliefs of teachers about the effectiveness for learning (i.e., personal factors) are a significant predictor of actual technology use [10]. For this reason, it is important to understand (and possibly influence) how teachers feel towards social robots if we intend to see them widely adopted. Teacher views may also highlight research questions that need to be addressed to demonstrate the efficacy and suitability of using robots in schools.

Previous pan-European work [11] found that views of teachers are generally positive, but that there are concerns over fairness to access, the robustness of the technology, and potential disruption to classrooms. Some of these same concerns were observed prior to an experiment in the USA, but after the experiment had been completed, views had changed [12]. Teachers expected the robot to be disruptive to the classroom, but found that it was not, although this is partially mitigated as headphones were used so that the possibility of audible disruption would be minimised. A large-scale survey conducted in South Korea [13] found that teachers were generally positive about the use of robots in education, but they were more negative than other stakeholders. Ethical tensions have also been identified pertaining to issues of privacy, robot role, socio-emotional effects on children and responsibility [14].

When exposed to a highly scripted interaction with a robot, teachers showed fairly positive reactions [15], however it was concluded that the interaction here was not related to the educational quality that the robot could offer, and this is

Fig. 1. 'Imagined' classroom with the human teacher present. This is used on the survey in the 'teacher' (TE) condition.

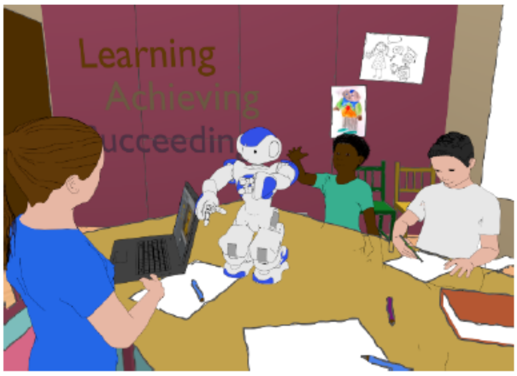

Fig. 2. 'Imagined' classroom without the human teacher present. This is used on the survey in the 'no teacher' (NT) condition.

where the focus should be. Incorporating the views of teachers in educational technology design has been highlighted as a particularly important aspect of creating a partnership that allows teachers to identify the benefits and shortcomings of technology when related to the curriculum [16]. This motivated us to consider how we might gather the opinions of both the general public and education professionals, with the aim of using the findings to direct future research.

Due to the technological nature of robots, it is anticipated that they will be seen as a tool for STEM education, rather than for the teaching of humanities. This is reflected in the research being conducted with robots in education: they are commonly applied in STEM education, with promising outcomes [17], although research is also prominent in language contexts [1], [4]–[6]. However, there are comparatively few robots being used to teach art or religious education, for instance (a reference to work in either of these domains could not be identified at the time of writing). These pre-conceptions will be explored as they could produce further barriers to adoption of the technology in certain areas (or indeed may highlight areas that should not even be attempted to be addressed with robots).

III. Hypotheses

From the related work outlined in the previous section and our prior experience, the following hypotheses were devised for this study:

- H1 *Context matters:* providing a minimal context will lead to more positive attitudes towards robots in education than the Eurobarometer [9] suggests.
- H2 *Robots for STEM:* robots will be seen as an educational tool for delivering science, technology, engineering and maths (STEM) content, but not for broader use in the arts or humanities.

Additionally, we seek to address the following exploratory question to build on prior research [11], [12], [14]: Q1 'what are some potential obstacles perceived by educators to the adoption of robots in the classroom and what can be done by researchers regarding these?'.

IV. Methodology

A. Survey Design

In order to gather the opinions required to address the hypotheses, we devised a survey to elicit the attitudes of people towards the use of social robots in education. Part of this survey was based on the questions asked in the Eurobarometer survey [9], whilst other questions were devised by the authors to specifically focus on areas of interest relating to the hypotheses and applications of robots in education. The full survey is not included here due to space restrictions, but can be viewed online: https://github.com/james-kennedy/r4lworkshop-survey.

Two versions of the survey were created: (1) with a picture with a teacher present (TE), and (2) without a teacher present (NT; Fig's. 1 and 2). This was done as a methodological check to explore whether the image provided to participants would shape their attitudes towards robots in schools. In both cases, the accompanying text was kept the same: a broad description of social robots and of their abilities in relation to learning ('the children can talk to the robots and learn from them', 'the robot can learn children's names and preferences', 'it can personalise learning experiences').

B. Participants

Two pools of participants were recruited to address the hypotheses: (1) education professionals from schools in the U.K., and (2) members of the general public. The members of the general public completed an online questionnaire via a crowdsourcing platform (http://www.crowdflower.com). The online responses were limited to the top 2 levels (indicating 'extremely high' previous response quality) of 'contributor' as judged by the crowdsourcing platform. Respondents were restricted to the U.K. (to match the education professionals country). All participants consented to having their responses used for research purposes. The general public were compensated with an amount commensurate with the national living wage at the time of execution; the educators received no compensation.

General public (GP): 100 responses were collected; 50 with each picture. The responses were manually checked and it was found that some responses were from the same users with multiple accounts (6 instances), whilst others were in fact from those working in education (7 instances). These responses were therefore removed, leaving a total of 87 responses (41 TE/46 NT). The average age of this sample was 35.3 years (*SD*=11.4), 29F/58M. Further demographic details (such as number of children and education level) were collected and will be explored as factors in the analysis in Sec. V.

Education professionals (EP): 35 responses were collected (19 TE/16 NT). The average age was 37.6 years (*SD*=11.5), with 2 not providing their age. The sample has a strong female bias (31F/4M), which reflects the gender balance in the U.K. for primary school employees. We focus on primary schools as this is the age commonly used in HRI research in education settings. The sample came from two schools; one in a rural location (18 responses), and one in a city (17 responses). Both class teachers and teaching assistants were included.

V. Results

Preliminary analysis was conducted to verify the reliability of the data. Cronbach's Alpha was calculated for an 8 item sub-scale of the survey that related to the acceptance of robots in education (questions 4 to 10 and 14). This was performed on 98 of the 122 total responses (due to non-responses or 'unsure' responses), resulting in $\alpha = .862$. This value indicates that the internal consistency of responses is high, so the data is likely to be reliable.

To test the stimulus manipulation, a comparison within each of the groups (EP and GP) was performed between those who had seen the survey with the teacher in the picture and those without the teacher. For this, Mann-Whitney U tests were conducted for the questions relating to acceptance of robots in education (the same ones as for Cronbach's Alpha: questions 4 to 10 and 14). No significant differences were found for any of the questions for the GP sample (U values varied from 666.5 to 904.0 and p values varied between .161 and .731). Nor were significant differences found for the EP sample ($49.0 < U < 140.5$; $.142 < p < .712$). This provides a strong indication that the change in picture stimulus did not cause significant differences in responses. Due to this, for the remaining analysis, no distinction will be made between the two conditions with (TE) and without (NT) teacher visible in the stimulus.

A. Interest in Technology and Positivity Towards Robots

When seeking to address Hypothesis 1, we identified a bias towards having a favourable view of technology in the data collected from the online survey. The first question of the survey asks how interested the participant is in science and technology (*very*, *moderately*, or *not at all*). For the EP, the split falls roughly in line with that of the Eurobarometer [9], but our general public view is clearly more interested (Table I). This is reflected in a comparison between the general public (Mdn=3) and educator (Mdn=2) responses using a Mann-Whitney test: $U = 1029.5, p = .002, r = .29$. This also carries through to how positive a view they hold about social robots (question 2; 5 point Likert from *very negative* to *very positive*). A Mann-Whitney test indicated that the general public held a more positive view of social robots (Mdn=4) than educators (Mdn=3), $U = 820, p = .001, r = .32$.

TABLE I
INTEREST IN SCIENCE AND TECHNOLOGY AS REPORTED BY SURVEY RESPONDENTS (AND THE EUROBAROMETER [9]).

Group	Very interested (%)	Moderately interested (%)	Not at all interested (%)
General public	61	37	2
Educators	31	57	12
Eurobarometer	25	47	28

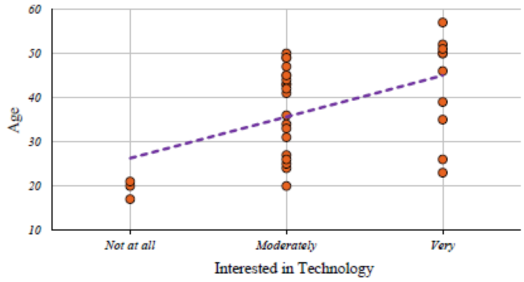

Fig. 3. A significant correlation is observed between educator age and interest in technology, with younger educators reporting to have less interest in technology.

These responses were correlated with the questions regarding views about the use of robots being used in education. It was found that a positive correlation exists between how positive a view someone has about social robots (question 2) and the role that a robot should play in child education for both educators ($r_s(25) = .561$, $p = .002$) and the general public ($r_s(84) = .390$, $p < .001$). These fundamental differences cause problems in comparing between educators and the general public, and the general public and the Eurobarometer findings. If it were reflective of differences between the general public and educators, then this would be an acceptable factor, but we hypothesise that it is instead because of a pro-technology bias caused by the online method used to gather general public responses. As such, a direct comparison would not be appropriate for exploring Hypothesis 1, nor can the EP and GP samples be considered homogeneously.

There is an observed positive correlation between age and interest in technology for educators ($r_s(31) = .492$, $p = .004$; Fig. 3), but not for the crowdsourced responses ($r_s(85) = -.093$, $p = .393$). This is probably due to the self-selecting nature of the crowdsourced participants, but is an interesting finding for the educators – this will be returned to in the discussion (Sec. VI).

Due to the differences between our crowdsourced sample and the Eurobarometer sample, a direct comparison that was intended to be explored as part of Hypothesis 1 (that providing

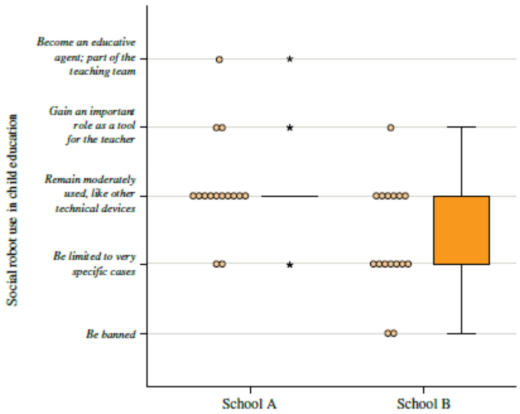

Fig. 4. Opinions from educators about how robots should ideally be used in child education split by school. This was a forced choice survey item, with an implicit scale from 1 to 5: 'be banned', 'be limited to very specific cases', 'remain moderately used, like other technical devices', 'gain an important role as a tool for the teacher', 'become an educative agent; part of the teaching team' (and an 'I don't know' option, not shown). * indicates outliers.

a context as we do in our survey will lead to more positive responses) would not be sound. However, it should be noted that the Eurobarometer reporting of 34% wanting robots to be banned in education was not reflected in our results, where only 2 respondents (both from the educator sample) want robots to be banned from use in education (Fig. 4).

B. Cultures Within Schools

To further explore the views of the education professionals, we compared the responses from the different schools. We find that despite there being no significant differences in interest in technology (School A: Mdn=2, School B: Mdn=2; Mann-Whitney $U = 123, p = .263, r = .19$), there are differences in attitudes towards the use of social robots in education. Question 14 on the survey (see Fig. 4) is particularly indicative of an overall view, asking how social robots should ideally be used in child education. These answers were converted to an ordinal scale, with *be banned* receiving the lowest score, and *become an educative agent; part of the teaching team* the highest. A Mann-Whitney U test found that a significant difference exists between School B (Mdn=2) and School A (Mdn=3), $U = 62, p = .012, r = .45$ (Fig. 4).

No significant demographic differences could be found between the two schools to explain the difference in attitudes, although their locations could be a factor. School A, which appears to be more open to the use of social robots in education is situated in a rural village (population approx. 7,000), whereas School B is within a reasonably large U.K. city (population approx. 250,000). We would hypothesise two possible explanations: (1) differing micro-cultures between large cities and small villages lead to different concerns for children's well-being, or (2) differing ethos between schools regarding their attitude in general towards teaching science and technology. The former will be discussed further in Sec. V-D,

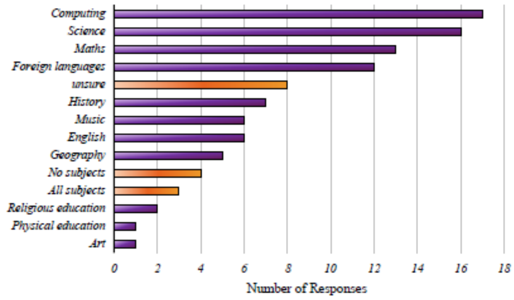

Fig. 5. Opinions from education professionals about the subjects in which they think social robots could be used to aid learning (forced choice survey item; multiple responses can be selected, leading to 101 total responses).

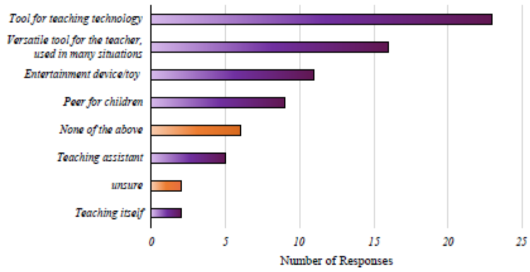

Fig. 6. Opinions from education professionals about how robots could be used in a school classroom (forced choice survey item; multiple responses can be selected, leading to 74 total responses).

but the latter would require further investigation to analyse the 'culture' within the schools.

C. Robots as a STEM Tool

Two questions on the survey were used to address how people perceived the uses of robots in terms of the content it could deliver, and in which role (Hypothesis 2). It was hypothesised that robots would be seen as a tool for delivering STEM education, and indeed this was supported through the data. Twenty of the 35 educators thought that the robot could be used to aid learning in computing (which covers programming, I.T., digital security, etc.), followed by science (19) and maths (16), with humanities such as art (4) and religious education (5) receiving very few responses (Fig. 5).

The survey question 11 asked about the envisioned role of social robots in the classroom, with several options ranging from an 'entertainment device', a 'tool', a 'peer for children', and a 'teacher itself' (see Fig. 6 for all options). In line with the results presented in Fig. 4 and in the previous paragraph, the education professionals mainly see robots as tools (Fig. 6) – again providing support for Hypothesis 2. In more than 30% of the cases, the EP also view the robot as a toy, which may reflect misconceptions or a lack of clarity about robots in a learning environment. We comment further on this point in the discussion.

TABLE II
PERCEIVED OBSTACLES TO ADOPTION, AS MENTIONED IN FREE TEXT ANSWERS TO QUESTION 15. PARTICIPANTS COULD MENTION SEVERAL ITEMS. THE PERCENTAGE OF RESPONDENTS MENTIONING THE ITEM IS PROVIDED FOR BOTH EDUCATION PROFESSIONALS (EP) AND THE GENERAL PUBLIC (GP) WITHIN EACH GROUP.

Obstacle	#EP	% of cases	#GP	% of cases
Source of distraction	10	34.5%	10	16.1%
Lack of social skills	9	31.0%	9	14.5%
Practical issues	7	24.1%	17	27.4%
of which, cost	*1*	*3.4%*	*12*	*19.4%*
Risk of isolation	6	20.7%	1	1.6%
Workload/orchestration load	5	17.2%	6	9.7%
Public perception	2	6.9%	10	16.1%
Ethical concerns	2	6.9%	1	1.6%
Safety	1	3.4%	2	3.2%
Technical limitations	1	3.4%	7	11.3%
Educational efficacy	0	0.0%	9	14.5%
Societal impact	0	0.0%	8	12.9%

D. *Perceived Obstacles to Adoption*

To explore Question 1 (Sec. III), a question was used to ask 'what would you see as the main obstacles for having robots in a classroom?'. This question had a free text answer so that responses were not constrained; an answer was not forced for this question. The responses from the educators provided many insights into the use of social robots in schools, often revealing deeper concerns that were hard to capture through other questions. Of the 35 EP respondents, 29 provided an answer for this question, and of the GP respondents, 62 provided an answer. We group these responses in a series of categories (formed by considering all responses), which are shown in Table II.

The most cited obstacle to adoption for EP is the robot being a potential source of distraction for the children – something that falls in line with prior research [11], [12]. However, this rather broad category could actually reflect the fact that teachers do not have a clear idea of what the robots could be used for (the context provided for the survey was minimal, so a precise role for the robot was not specified). In contrast, the most cited obstacle perceived by the GP sample were practical issues, and in particular, the cost of the robot. Cost was not mentioned in the survey at any stage, so this indicates that there is a pre-conception that these robotic devices would be expensive (or at least more expensive than schools can afford).

The perceived lack of social skills (simplistic interactions, lack of empathy, lack of flexibility) of robots gives a complementary picture of the current perception of robots by the education professionals: they are primarily seen as a scripted, reactive machine. This issue was somewhat surprising as it had not commonly been raised as an issue in prior work. More expectedly, a range of practical issues (cost, maintenance, space requirements) are mentioned, but usually along with other factors. Contrary to the perception by the general public, they do not appear to be the teachers' main concern at this stage.

Another factor that had not been hypothesised was the mention by several teachers of an increased risk of child isolation (for example, one comment read: 'I consider that many of our children are already isolated and this could isolate and potentially marginalise them further'). This would support the pushing forward of social approaches to child-robot interaction, like robot-mediated collaborative learning (i.e., using technology to further encourage interactions between child peers).

Some concerns were also raised in relation to the increased workload or classroom orchestration load brought by the robots for the teachers. These issues have been studied in the context of computer-supported learning (for instance [18]), but are yet to be fully considered in the field of 'robot-supported' learning.

Finally, surprisingly few ethical and safety-related concerns were raised. Such concerns do not appear to be prevalent amongst the EP respondents.

E. *Demographic Factors*

Other demographic factors in the education professionals sample (age, gender, number of children, education level) do not appear to have an impact on opinions about how social robots should be used in child education. Linear ordinal regression does not reveal a statistically significant factor when considering participant age, gender, number of children, or education level (Nagelkerke pseudo $R^2 = .146$, so the demographic factors only account for around 15% of the variance in how participants believe social robots should be used in child education). A model with a high goodness-of-fit could not be found when performing the same regression on the data from the general public (possibly due to the sample bias towards high interest in technology overpowering the other factors).

VI. DISCUSSION

A bias towards a positive view of science and technology was introduced through the means of collecting responses from the general public - via an online crowdsourcing service. This prevented us from directly addressing Hypothesis 1 through a comparison to the Eurobarometer survey data. However, we do see that there is a general openness to using social robots in education, although education professionals may approach this with a degree of caution (Fig. 4, Sec. V-D). There is also a strong pre-conception from educators that social robots would be suitable for teaching STEM subjects, adopting the role of a tool, rather than as an educative agent (Hypothesis 2, Sec. V-C, Fig. 5). These findings were observed regardless of whether respondents had been presented with a picture including a teacher, or not including a teacher in the introductory context for the survey (Sec. V).

Some perceptions based on pre-conceptions may well change with greater exposure to social robots that can do more than be used as a tool for STEM subjects (for example, as recently shown with handwriting learning [5]). However, a general lack of interest in science and technology (particularly from younger educators – Sec. V-A) could produce greater, and cyclical barriers to use. It has been shown that there are links between teacher interest and confidence in teaching subjects [19], as well as reciprocal effects between teachers and child in engagement in learning [20]. It follows that if teachers are less interested in teaching technology, students will be reciprocally less interested, they will learn less [21], and be less likely to continue study of that subject [22]. This presents a concerning cycle wherein those students who eventually become teachers are also likely to lack interest in teaching those same subjects. The lack of interest of younger teachers for technology also comes as a surprise as one would typically expect younger teachers to be more engaged with computer-related technologies.

This is potentially where the broader aspects of using a social robot could be beneficial in breaking down some barriers to use. The robot is a technological device, but could be used to teach a variety of subjects with an element of sociality. The use of the robot could stimulate interest in technology, and the social aspects of robot behaviour could be used to create reciprocal interest in those subjects (as has been attempted for some aspects of behaviour [23]). This calls for a greater exposure of teachers to our robotic systems, so that they better comprehend the capabilities, current limited performance, and possible future applications of social robots in education.

Successfully addressing the concerns highlighted by educators in Sec. V-D (in relation to Question 1, Sec. III) would provide an essential first step towards this goal. Some of the concerns may arguably be alleviated once the teachers (and the children) familiarise themselves with the robots (the robot being a source of distraction is likely to resolve quickly after novelty goes away) or once the penetration of robots in classrooms increases to a point where dedicated companies could regularly take over training and maintenance issues. However, other issues, like the richness of the interaction, the adaptability of the robots to rapidly (or, on the contrary, slowly) change in response to child behaviours, or the suitability of social robots to develop children's peer-group sociality, present more fundamental questions. We believe that these behavioural considerations must remain central to the research agenda of child-robot interaction.

VII. Conclusion

Overall, we find that the attitude towards social robots in schools is cautious, but potentially accepting (in line with previous findings [13]). The perceived obstacles to adoption of robots in classrooms which the education professionals highlight raised some surprising considerations, such as potential isolation of students which would warrant further long-term study. For the educators, concerns about appropriate social skills for the robots dominate over practical and ethical concerns, suggesting that this should remain a focus for child-robot interaction research.

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