Are There Limits to Science?

Edited By

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CHAPTER ELEVEN

WAYS TO DEVELOP STUDENTS' APPRECIATION OF THE POWER AND LIMITATIONS OF SCIENCE

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1. Introduction

This chapter describes the rationale for and impact of a workshop for teenagers called, "Can a robot hear?" The workshop was designed to help students aged 14-16 to progress in their appreciation of the power, relevance and limitations of science when addressing big questions in multidisciplinary arenas.

Robots that seem to be context-aware and autonomous are becoming increasingly present in homes, hospitals, care homes and other institutions. Perhaps unsurprisingly, given the pace of change, there is much research to do to discover how schools can best prepare young people for the questions they are likely to encounter as the co-workers, consumers and inventors of increasingly humanlike machines.

The design of this workshop was prompted by research conducted by LASAR (Learning about Science and Religion). LASAR is a research and dissemination enterprise which seeks to understand how questions bridging science and religion are managed at school. For our team, the opportunity to develop a workshop on the advance of robotics stood out as one that can capitalise on the research we already have underway. Firstly the prospect of finding out about humanoid robots is one that appeals to most teenagers (Billingsley 2016); secondly the theme raises philosophical questions such as whether humans and artificial entities are on a continuum or whether a person will always be a step beyond anything a robot can become; thirdly there are cognitive, sociological and pedagogical questions to address relating to how young people reason

about this question and what opportunities they have in school to develop more scholarly responses.

Calls for schools to give young people more teaching to help them with multidisciplinary and real world contexts have been made for some time. Teaching through subjects is valued within education as a way to immerse students into each of the disciplines. Today, however, subject compartmentalisation has become entrenched and pervasive across the stages of education – each subject tends to work as a silo, with its own curriculum, text books, subject examinations, subject-specific teacher training and – in secondary schools – its own specialist teachers and classrooms. These boundaries are detected by students who then constrain their questions and thinking in the way they suppose their teacher prefers (Billingsley, Brock, Taber, & Riga 2016). Thus and for example, David (not his real name) was one of many 14 year old students who explained that students hold back questions they perceive as "off-topic" and/or culturally sensitive (Billingsley, Taber, Riga, & Newdick 2012).

With this in mind, we anticipated that a series of workshops on the theme of humanoid robotics could provide ways to raise teenagers' appreciation of what it means to be human and deepen their understanding of how science, religion and other disciplines inform our thinking about these questions. For example the puzzle of whether and why a person has a capacity for self-determination is longstanding. Today we are not only searching for answers for ourselves to satisfy our philosophical curiosity but are also trying to work out what we should be saying about the progress of increasingly humanlike machines. If having free will and a moral code and a sense of responsibility are aspects of humans that we can understand mechanistically then arguably we can build robots that also have these capacities. Alongside these intriguing questions, we envisaged that these workshops would provide a space in which teachers could draw students' attention to careers in engineering and in the caring professions and the notion that there are careers that would focus on both.

2. Aims and development of the workshop

The robotics workshops we are designing form part of a research journey that has employed surveys, focus group discussions, interviews, and intervention studies with more than 4000 school students.

The research has identified a number of gaps in the education children currently receive to do with developing students' appreciation of how to manage so-called Big Questions – which is to say – questions which most scholars agree cannot currently or potentially ever be resolved using

science alone. For the first workshop in the series we focus on the aim of developing students' appreciation of the nature, power and limitations of science. The key ideas we address in the workshop emerged from some of our exploratory focus group and interview studies (Billingsley 2013, 2016; Billingsley et al. 2016). We also consult regularly with philosophers and theologians, biologists, engineers and philosophers and, on occasions, our expert scholars have joined us to run workshops in schools. In all, developing and fine tuning the workshop has taken place over a period of about a year with our team delivering the workshop many times with small changes each time. These changes were partly to become more effective at achieving the objectives and partly on the basis of student and teacher feedback.

The primary aim of the workshop is to develop ideas and pedagogies which teachers can use to introduce students to the ideas that (a) some questions are more amenable to science than others; and (b) that some questions are more metaphysically sensitive than others. The rationale for these objectives is as follows. This period of schooling (for students age 15-16) is the last stage in which students are required to study both science and non-science subjects and so the last opportunity to ensure that all students experience the specified teaching. In our proposed schema for progression, these two objectives provide, we argue, all students with some essential and key ideas about the ways in which scholars approach big questions and the power and limitations of science within those approaches. We have noted when designing our schema for progression that there is already an objective in the National science curriculum in England for this age group which says that students should develop an appreciation of "the power and limitations of science" (DfE, 2014, p. 5). This corresponds to the objective in our schema that students should appreciate that some questions are more amenable to science than others. We recommend (however) that teaching relating to this objective begins in lower secondary school. We deem it to be important for students in this final stage of statutory education to also know that there is a diversity of scientific opinion on the extent to which so-called Big Questions can eventually be resolved scientifically. For this reason we have added the objective that "some questions are more metaphysically sensitive than others". Given that the aims and approach are novel, we have been particularly pleased to find when we review feedback from teachers and students that participants seem to be picking up the objectives we are endeavoring to cover. For example we ran the day at a school event where there were many workshops on different themes with different presenters.

The event organizers picked out one piece of feedback for each workshop. For our workshop the feedback was:

> *That depending on your metaphysical position, your opinions and furthermore answers to certain questions vary. It was awesome, my favourite by far. Was really interesting and the class had really good discussions. It opened my eyes a lot to the opinions of others and as to what metaphysics is about.*

In addition to testing the efficacy of the workshop itself, we are also keen to develop a workshop that can be carried out by staff in the school and so incorporated more widely into schools' curriculum planning. When we run the workshop in schools, we invite teachers from the relevant subjects (RE, computer science and science) to assist and/or watch. We have noticed in so doing, the value of interdepartmental collaboration and also the importance of recognising that the expertise and pedagogies needed to teach this workshop are likely to go beyond the expertise and experience that is usually found with one subject teacher. In particular our experience has been that RE teachers frequently have the expertise needed to help students with the philosophical aspects of the workshop while computer science teachers frequently help when we move to technology-related questions. Thus, for example, an RE teacher worked with students to help them to understand that the question of "how many neurons are in the brain" is less metaphysically sensitive than "can a robot have a mind?". In another workshop, a computer science teacher reinforced a teaching point about the greater complexity of attempting to build a robot that can hear over a robot that can respond to sound.

A third aim underpinning the research is to look at whether interdisciplinary workshops such as this one can increase the size and diversity of the cohort of students who feel attracted to the idea of a science-related career. This possibility is motivated by the circumspection that young people who enjoy multidisciplinary ways of thinking may feel more positively towards science if they are given examples of the ways in which science can inform our thinking about a big question without requiring a commitment to the stance that science is sufficient on its own. The workshops have provided some support for this idea, with teachers often commenting that the workshop is particularly well received by girls who (as our own and other research indicates) are more likely than boys to favour teaching which makes links between different subjects.

As a result of many cycles of trials and we feel we are now in a position to offer teachers a workshop with pedagogies and assessment tools that they can use themselves to develop and assess students'

capacities to reason about the power and limitations of science. The next section of this chapter sets out the details of the workshop including the overview, objectives, activities and the concluding remarks from the workshop. We will also introduce some of the assessment tools that we use to examine to what extent the workshop attendees have met the teaching objectives. Finally in the chapter we set out and discuss the findings from the assessment carried out by students.

3. Workshop outline-Can a robot hear?

a. Overview

In the opening of the workshop, students are presented with a headline which claims that a robot has been invented which can hear. They are asked to consider what criteria they feel should be used to decide whether or not the robot really can hear. Is it sufficient if the robot responds to a sound? Should the robot also demonstrate a level of understanding and if so how and what level? Finally students compare the difficulties of addressing and assessing each of these challenges-a robot that can respond to sound / a robot that can hear; a robot that can understand / a robot that appears to understand.

The workshop helps students find the critical questions to ask when reporters use words associated with human experiences and capacities when talking about technology. It also introduces the idea that some questions are more amenable to science than others.

b. Objectives

The objectives are for students:

- to be able to critically analyse the language used to describe human/robot behaviours, to draw attention to linguistic distinctions that enable further discussions about the progress of robotics towards humanlike machines (Ep LO1);
- to appreciate that some questions are more amenable to scientific methods than others (Ep LO2);
- to appreciate that some questions are more metaphysically sensitive that others (Ep LO3);
- to appreciate that the scientific community is diverse and have a range of metaphysical positions on whether human experience and behaviour can be reduced to properties that are amenable to science (Ep LO4).

c. Session structure

Introducing the terms: "bridging questions" and "interdisciplinary questions"

The workshop begins by explaining that different subjects such as history, economics, science, philosophy, art and computer science, investigate different questions, and students may have particular interest in one or more of them. (The facilitator may ask students, "who likes history? Who likes science? Who likes engineering" and so on).

Then it is explained that there are some questions that students might be interested in, but that could not be investigated by any one of these disciplines alone. These are called bridging questions or interdisciplinary questions. (The facilitator asks students if they could suggest some interdisciplinary questions.) Then the facilitator explains that in the workshop they are going to think about some questions that robot engineers in particular are interested in, and that these questions are better understood and possibly better answered if we bring several disciplines into the discussion.

Workshop activity: can a robot hear?

The facilitator asks students to give their opinions about whether we can design and build a robot that can hear. There is a work sheet with these two questions:

1) Suppose you were designing a robot that can hear – how would you address that challenge?
2) How would the robot demonstrate that it can hear (if it can hear)?

Then the facilitator demonstrates a robot that starts and stops moving on the sound of a clap and again asks the question, "Can this robot hear?" The aim is to help students consider whether there is a distinction between "hearing" and "responding to sound". Students are asked whether there is a difference between a person hearing and a robot hearing. Pupils may suggest that "understanding" or "emotions" are involved in the person hearing. The list of the differences between a robot hearing and a person hearing is written on the board by the facilitator. (Participants may suggest

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that hearing for a person is more complicated than just a responding to a clap. In that case, the facilitator may ask what about a Siri: Does Siri hear what the user says and if this is hearing how this is different from a person hearing?) During the discussion among students, the facilitator should try to highlight two different answers that students may give to the question of whether hearing is the same as responding to sound. One view is that "hearing and responding to sound are the same", the other is that "a robot responding to sound is different from a human being hearing" (the facilitator refers back to this distinction later).

Workshop activity: the difference between a humanoid robot and a human being

The facilitator explains what a humanoid robot is (perhaps showing some interesting photos or video clips). She/he asks the group of students to do a simple task (such as raising their hands a couple of times). Then the facilitator asks the students to imagine that there is a group of humanoid robots in one room and a group of students in another room, and that both groups have been asked to follow the same instruction (raising their hand). The facilitator asks, what are the similarities and what are the differences between these groups and what they are doing. The point is to discuss the difference of "rule following" between programmed humanoid robots and the human beings. These are the questions for thinking and discussion:

- Would the robot get tired if we asked them to do this for many, many times? Would that be a difference between a humanoid robot and a human being? (If students say robots never get tired in the way that a human being gets tired, the facilitator may ask them to list the signs of tiredness in humans and say, "How about if I give this list to an engineer and ask for a group of robots that show all these signs after repeating the job for a certain number of times? Does this reduce or even fill in the gap between the robots and the human beings?");
- Do you think that any of the humans or robots or both would start to get cross if they are asked to do this for several times? (The facilitator can then say that the engineers will be asked to address this gap in their design.);
- Do you think that any of the humans or robots or both would refuse to follow the instruction after a while? (The facilitator can again say that this will be addressed in the design of the robots.);
- Does the robot group understand what they are doing?

The facilitator broadens the question and asks whether, in general, engineers can fill the gap between humanoid robots and human beings? Then the facilitator explains that before answering this question she needs to introduce some terms.

Metaphysically sensitive questions

The facilitator introduces the term "metaphysically sensitive question" by saying that whether scientists can fill the gap between a humanoid robot and a human being is an example of a "metaphysically sensitive question". This is because the answer might be different based on our understanding of "what it means to be human".

To explain this further, the facilitator gives a definition of "metaphysics":

> *Metaphysics is the study of any of the most fundamental concepts and beliefs, on which many other concepts and beliefs rest. Or, metaphysics discusses the question of what is real.*

The facilitator then goes back to the question of hearing and the list of the differences between hearing and responding to sound and explains that the question of "can a robot hear?" is also a metaphysically sensitive question because how we answer depends on what we mean by "a human being hearing".

If a person is just molecules and atoms and an assembly of mechanisms then we are well on the way to having a robot that can behave like a human. If however, hearing is more than a mechanical process and also requires some kind of personal experience and subjective response then this will be more difficult to achieve in a robot and, further, we may never know for sure if a robot is merely displaying the signs of hearing or if there is truly hearing happening too.

In order to help students better understand the idea of "metaphysically sensitive" questions, the facilitator then gives them some examples of less metaphysically sensitive questions:

- Does this robot respond to sound?
- How many batteries does this robot need?
- What is the maximum weight that this robot can pick up?
- How many neurons are in an adult brain?

The facilitator highlights that if a question is not metaphysically sensitive then it is likely that scientists will agree that the question is amenable to

science. In contrast, scientists who hold different metaphysical positions are likely to disagree over how to answer a metaphysically sensitive question – and in particular may not agree about the amenability of the question to science.

Workshop activity: ordering questions from amenable to science to more metaphysically sensitive

The facilitator gives 8 cards with questions that are more or less amenable to science on each and asks them to categorise them into (a) very amenable to science; (b) partly amenable to science; (c) not very amenable to science – but there may be smaller scientific questions that we can usefully explore. A worksheet for this and other activities can be found on the LASAR website – as LASARcentre.com and also our newly developed site for teachers looking to develop students' epistemic insight at epistemicinsight.com.

Workshop concluding remarks

The facilitator sums up by highlighting the following points from the workshop:

1. In this workshop, we discussed what an "interdisciplinary question is" and how science and engineering interact with other disciplines such as psychology and philosophy.
2. In this workshop, we discussed the meaning of the word "hearing" and the importance of being clear about what we mean when we use it to describe what a robot and a person do when they respond to sound.
3. We discussed whether it would be possible in the future for science and engineering to fill the gap between a humanoid and a human being. We also asked, if not, what might be special about being human that cannot be produced by science and engineering?
4. We discussed what a "metaphysical view" is and what it means that a question is "metaphysically sensitive".
5. We discussed that the question of hearing is a "metaphysically sensitive question", we also discussed other examples of metaphysically sensitive questions.
6. We discussed that scientists cannot fully answer a metaphysically sensitive question.

7. We discussed that scientists with different metaphysical views may not agree on metaphysically sensitive questions.

4. Findings

The data collected from the survey conducted before the workshop revealed that two thirds of students believe that "One day there will be robots that are as intelligent as humans" while about a third agree that "One day there will be robots that have minds". Only 6% agree that "One day there will be robots that have souls".

In the pre-workshop and post-workshop survey we asked students, "Which of the following questions is more metaphysically sensitive 'Why does my pen still exist?', or 'Why does my pen fall to the ground?'". They also had the option to choose, "I don't understand the question". In the pre-workshop survey only one in three of the respondents gave the correct answer, while in the post workshop survey about 70% gave the correct answer.

Similarly in another question in the pre-workshop and post-workshop survey we asked students, "Which of the following questions is more metaphysically sensitive: 'Can a robot talk?', or 'Can a robot make sounds?'". Again they had the option to choose, "I don't understand the question". In the pre-workshop survey 62% gave the correct answer, while in the post workshop 88% gave the expected answer.

In the post-workshop survey we also asked students how their thinking has changed and below is a sample of comments from students attended the workshop:

- I have questioned the difference between hearing and responding which is particularly significant in terms of understanding of robot.
- I was made to think about inter-disciplinary questions and about hard questions.
- I can appreciate the difference between hearing and responding and it has developed my ethical views about robots.
- I am thinking more metaphysical. Science is not all about grades.
- Now I think there is a way bigger question and meaning to think about with robots and humans.
- My thinking has changed by me now knowing what counts as hearing and listening compared to responding to sound.
- It has enabled me to think about the source of our mental thoughts and if it is possible to implement senses and the power of thoughts into machinery/robots

5. Conclusion

In this chapter, we described a workshop on robotics designed for secondary students. The workshop aimed to help students develop their epistemic insight and particularly their appreciation that some questions are more amenable to science while others are more metaphysically sensitive.

The other learning objective of the workshop was to draw attention to attributions such as hearing and understanding, and the question of whether human beings and robots differ or not in relation to these tasks. We aimed to help students appreciate that the scientific community is diverse in understanding the differences between a human being and an advanced robot. The result from the surveys conducted before and after the workshop revealed that robots vs. human is an engaging topic for students that helps them make links between science, religion and other disciplines. The workshop was effective in bringing clear evidence of change in students' thinking about the power and limitations of science. Our experience of developing the workshop on the uses and understandings of robotics indicated that this theme provides a great opportunity for exploring interdisciplinary questions. We are currently designing and testing more workshops related to robots, including "can a robot care?" and "can a robot fall in love". The report on these workshops will be published in the near future.

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