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Glenn Ellis
Smith College, gellis@smith.edu

Jake Lauer
Smith College

Katie Silva
Smith College

Netty Nina
Smith College

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AC 2007-1006: ASSESSING HIGH SCHOOL GIRLS' PRECONCEPTIONS ABOUT ARTIFICIAL INTELLIGENCE TO IMPROVE LEARNING

Glenn Ellis, Smith College

Jake Lauer, Smith College

Katie Silva, Smith College

Netty Nina, Smith College

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Assessing Preconceptions about Artificial Intelligence to Improve Learning

I. Introduction

> *Students come to the classroom with preconceptions about how the world works. If their initial understanding is not engaged, they may fail to grasp the new concepts and information that are taught, or they may learn them for purposes of a test but revert to their preconceptions outside the classroom.*
>
> --The National Research Council (one of 3 critical findings) [1]

Artificial intelligence (AI) is being used increasingly in the K-12 classroom as a means to engage students in learning about engineering and technology. This increase is due to a variety of reasons including: the changing importance of AI in our daily lives; a greater emphasis on science, technology and engineering in state educational frameworks; recognition of AI as a useful pedagogical tool for active learning; and the development of robotics kits that make AI accessible to younger learners. For example, a variety of in-school and after-school curricula use LEGO robotics kits to promote hands-on learning and exploration of programming, engineering design, principles in physical science and other content areas.[2,3,4] Another example is the FIRST Robotics Competition[5]. In this competition over 30,000 high school students participate in an intensive robotic design experience that receives national media attention. In addition to robotics, educators are also developing curricula that allow students to learn about other aspects of AI and explore some of the important issues facing the field. In one example, topics in AI are investigated using philosophy of the mind as a conceptual framework to help students develop meaningful connections among AI, philosophy, science, mathematics and other fields.[6,7] All of these varying approaches and others not mentioned share the common thread that a learner's prior knowledge will have a profound effect on the learning that takes place.

Despite the increasing importance of AI in pre-college education, little is known about the prior knowledge and preconceptions that students bring to the classroom. Yet it is well understood from numerous studies that prior knowledge strongly influences the integration of new information.[1,8,9] The National Research Council (NRC) writes:

> A logical extension of the view that new knowledge must be constructed from existing knowledge is that teachers need to pay attention to the incomplete understandings, the false beliefs, and the naïve renditions of concepts that learners bring with them to a given subject. Teachers then need to build on these ideas in ways that help each student achieve a more mature understanding. If students' initial ideas and beliefs are ignored, the understandings that they develop can be very different from what the teacher intends.[1]

What do students think AI is? Do they see it as being anything more than robotics? How do they see robots and humans as being different? Do they view AI as beneficial or harmful to

humanity? An improved understanding of how students answer questions like these will help uncover their preconceptions and target their issues of interest—and thereby allow for the design of more engaging curricula. Improved learning will occur by designing activities that focus on addressing misconceptions and helping students construct new knowledge. The need for identifying preconceptions is particularly true when the intended learning outcomes include developing a deeper understanding of the big issues related to AI, such as its theoretical limitations (if any), the relationship between AI and human intelligence, its ethical application, and so on. This is because students may already have strongly held beliefs about these topics that are not easily changed without full engagement.

To begin addressing this need for identifying student knowledge about the field of AI and the future of technology, this paper presents two data sets that provide insight into the preconceptions of middle and high school students. In the first data set, essays and drawings produced by middle school students are evaluated and gender differences are investigated. In the second data set, high school girls participating in a science and engineering camp are surveyed to assess their attitudes and understanding about AI.

II. Data Collection

JFK Data Set

The first data set was collected from the JFK Middle School in Northampton, Massachusetts in May of 2006. A total of 81 students participated, including 37 boys and 44 girls. The ethnic breakdown for the school is 5% Asian, 12% Hispanic, 3% black, and 80% white. It is reported that 18% of the students are eligible for free or reduced lunch.[10]

The data was collected by analyzing the student work produced by five sections of a seventh-grade Language Arts class at the beginning of an integrated AI, language and philosophy unit. The students in these classes included all academic levels and interests. To begin the unit, the teacher asked students to draw a picture of what they think AI is, accompanied by a one-page essay explaining their picture and their connotative definition of the field. These drawings and explanations were examined by the authors to identify patterns and gender differences in their responses.

SSEP Data Set

The second data set was collected from students participating in the 2006 Smith Summer Science and Engineering Program (SSEP). This four-week program, held at Smith College for high school girls, is designed to enhance the participants' understanding of science and engineering and inspire them to continue their study in these areas in college.[11] Students applying for the program are selected through a competitive process that encourages the participation of girls with a wide range of interests and talents. Through recruitment efforts and an extensive scholarship program aimed at achieving geographic, socio-economic, and ethnic diversity, a diverse group of 98 participants was chosen to attend the program in 2006. The ethnic breakdown for the participants was 14% Asian, 18% Hispanic, 19% black, 52% white, 7% native American and 1% Pacific Islander.

The data set for this study was assembled by surveying all the available students in the program during one evening session. A total of 75 students from varying grade levels (9^{th} grade: 17; 10^{th} grade: 15; 11^{th} grade: 16 and; 12^{th} grade: 26) participated in the survey. As shown in Figure 1, the survey consisted of two parts. In the first part, six questions were asked to obtain general background information, including student attitudes towards language arts; math, science and technology; and AI. In the second part, eight open-ended questions were used to assess their content understanding of AI and their opinions on some of the important issues in the field. The design of these questions was based upon an increasingly popular *backwards design* approach used by pre-college teachers for assessing student understanding and developing curricula that promotes meaningful learning.

For the following questions: SD = strongly disagree; D = disagree; N = neutral; A = agree and SA = strongly agree.

1.	I like using computers.	SD	D	N	A	SA
2.	I am good at using computers.	SD	D	N	A	SA
3.	I like English/language arts classes.	SD	D	N	A	SA
4.	I like mathematics, science and technology class.	SD	D	N	A	SA
5.	I generally get good grades in school.	SD	D	N	A	SA
6.	I would like to learn more about AI.	SD	D	N	A	SA

For most of the following questions, there are no right answers. Please just tell us what you think.

7. Explain how a robot works. [explanation]
8. Robots are one example of AI. Please list other examples. [application]
9. Some people think we can make a computer that thinks, acts and feels just like a human does. What do you think? [interpretation, self knowledge, interpretation]
10. Other than this survey, how have you learned about artificial intelligence? [self knowledge]
11. In what ways does AI affect your life now? How could it in the future? [self knowledge, application]
12. How can AI be beneficial to people? How could it be harmful? [application, empathy]
13. In what ways are computers and humans alike? In what ways are they different? [interpretation]
14. Would it be wrong to harm a robot? Explain. [empathy, self knowledge]

Figure 1: SSEP Survey Questions. Note: the facets of understanding being addressed in questions 7-14 are indicated in brackets and were not included in the student surveys.

Wiggins and McTighe[12] attempt to guide teachers in applying the research on learning by promoting a backwards design process—i.e., starting with measurable outcomes and working backwards to design meaningful learning experiences to help students achieve those outcomes. Key to this approach are assessment strategies and tools that measures deep understanding. To this end, Wiggins and McTighe have developed six facets that make up a mature understanding. They write that we truly understand when we

- can *explain*: provide thorough, supported, and justifiable accounts of phenomena, facts, and data.
- can *interpret*: tell meaningful stories; offer apt translations; provide a revealing historical or personal dimension to ideas and events; make it personal or accessible through images, anecdotes, analogies, and models.
- can *apply*: effectively use and adapt what we know in diverse contexts.
- have *perspective*: see and hear points of view through critical eyes and ears; see the big picture.
- can *empathize*: find value in what others might find odd, alien, or implausible; perceive sensitively on the basis of prior direct experience.
- have *self-knowledge*: perceive the personal style, prejudices, projections, and habits of mind that both shape and impede our own understanding; we are aware of what we do not understand and why understanding is so hard.[12]

Questions 7-14 in Figure 1 were designed so that each facet is assessed. The facets primarily addressed by each question are indicated in brackets after each question in the figure.

III. Results

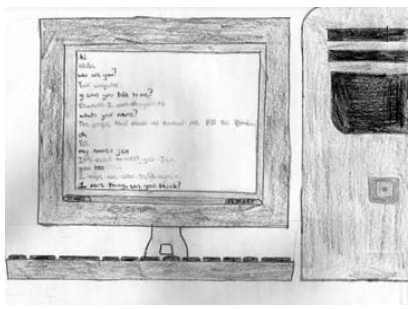
JFK Data Set

A summary of the features of the drawings and essays produced by the seventh-grade students at JFK middle school are shown in Table 1. Most students indicated that AI is either a robot or computer. Usually, there was no clear indication of gender (see Figure 2b). Students also illustrated a positive vision of AI in almost half of the cases and at a higher rate than a negative one. Examples of student drawings are shown in Figure 2. In their essays students often mentioned emotions and intelligence. Students were much more likely to mention that AI systems cannot have emotions or feelings than the opposite view. Many mentioned that AI helps people, while only a few expressed a fear of AI.

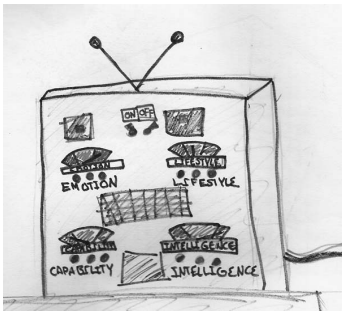
Statistically significant gender differences were found in the following features of the student drawings. Girls were more likely to draw a computer (see Figure 2a); something other than a robot (see Figure 2f), computer or computer chip; or a female robot/representation (see Figure 2g). Boys were more likely to draw a negative portrayal of AI (see Figure 2d). In the essays, the only statistically significant gender difference was that boys were less likely to mention either intelligence or emotion.

DRAWING					
Feature	**Response**	**Percentage with Response**			**p-value**
		Total	**Boys**	**Girls**	
Subject of Drawing	Robot with human-like qualities	51	49	51	0.57
	Computer	36	22	49	0.04
	Computer chip	7	10	5	0.30
	Other	23	7	39	0.00
Negative or Positive Portrayal	Negative	14	22	5	0.01
	Positive	47	34	59	0.13
	Could not tell	40	34	44	0.78
Gender of Robot/Representation	Male	19	24	12	0.07
	Female	11	0	22	0.00
	Neutral or Could Not Tell	69	63	73	0.84
ESSAY					
Feature	**Response**	**Percentage with Response**			**p-value**
		Total	**Boys**	**Girls**	
Mentioned Emotion or Intelligence	Emotion	60	51	68	0.53
	Intelligence	32	34	29	0.31
	None/Neither	17	32	2	0.00
AI can have Feelings or Emotions	Yes	12	10	15	0.70
	No, AI will Never have emotions	43	37	49	0.66
	Maybe in the future	5	5	5	0.86
AI Helps People		58	54	61	0.81
Mentioned a Fear of AI		6	10	2	0.13
Mentioned Weapons/War		4	7	0	0.07

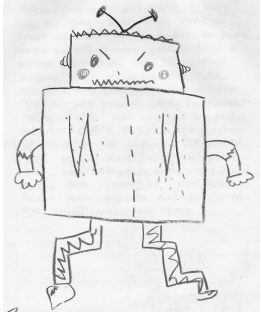
Table 1: Features of AI drawings and essays produced by 7th grade students at JFK Middle School, Northampton, MA.



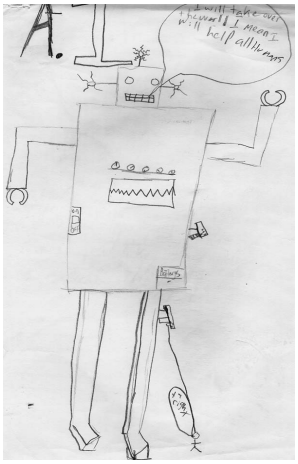
(a)



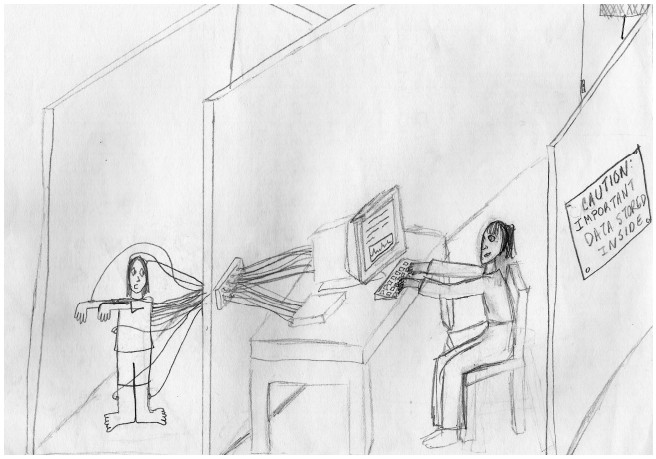
(b)



(c)



(d)



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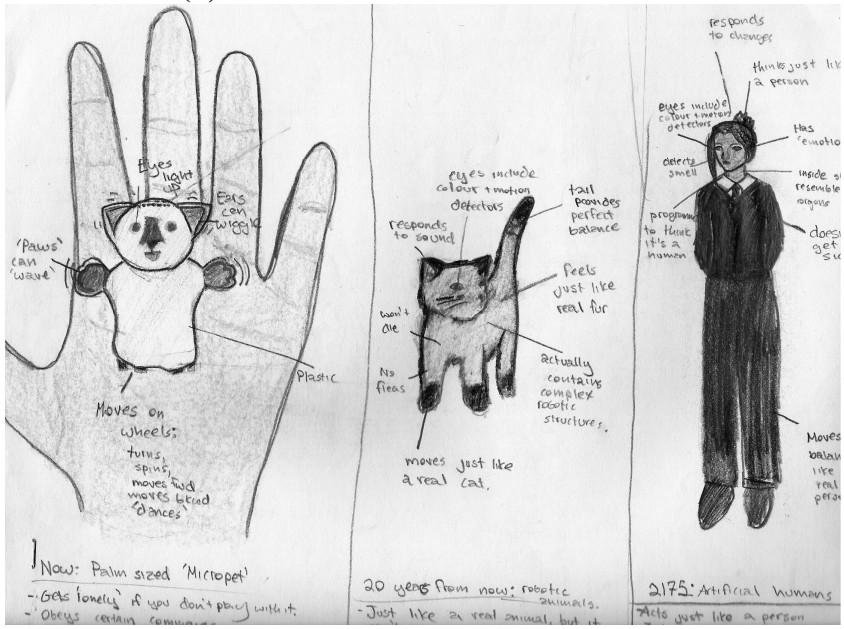
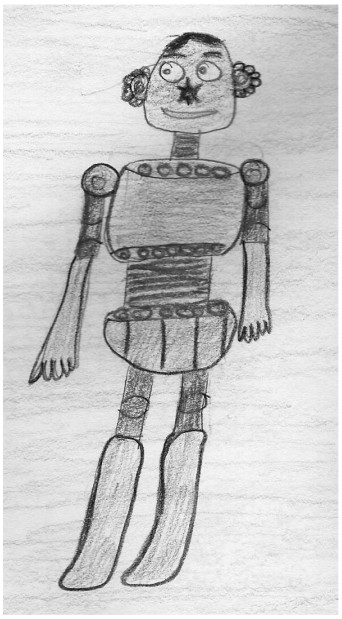


(f)



(g)

Gender of Artist: **(a)** Female; **(b)** Male; **(c)** Male; **(d)** Male; **(e)** Female; **(f)** Female; **(g)** Female

Figure 2: Illustrations of AI produced by 7th grade students at JFK Middle School, Northampton, MA.

SSEP Data Set

Table 2 shows general information for the high school girls participating in the survey. Because they have self-selected to attend a science and engineering summer camp, it is not surprising that they report liking math, science and technology class (91%), and using computers (89%). Most report that they are good at using computers (73%) and generally get good grades in school (95%). Many also report that they like their English/Language Arts classes (64%). The majority agree that they would like to learn more about AI (61%), but many are neutral on the subject (29%).

	Strongly Disagree (%)	*Disagree (%)*	*Neutral (%)*	*Agree (%)*	*Strongly Agree (%)*
1) I like using computers.	0	0	9	33	56
2) I am good at using computers.	1	5	21	44	29
3) I like English/Language Arts classes.	4	7	24	36	28
4) I like mathematics, science and technology class.	0	1	7	31	60
5) I generally get good grades in school	0	0	3	29	66
6) I would like to learn more about AI.	0	7	29	33	28

Table 2: Results for questions 1-6 of the SSEP survey.

Table 3 presents a summary of the student responses to the open-ended questions in Figure 1. From these responses we found the following:

- **Very few students demonstrated an understanding of how a robot functions.** They showed an understanding that programming is a key issue, but in most cases they did not understand what that means. Only a handful of students showed real understanding in their answers. "All robots have a power supply, a physical structure for movement, a brain either in it or outside (computer for example), a sensor to let it know its environment, and a motor of some sort that helps the movement."

- **Students overwhelmingly mentioned computers as an example of AI other than robots.** Often, students simply wrote "computers" with no extrapolation. Some, though, did give more specific examples. One student cited computers that play chess against human chess masters. Others noted computers and cell phones that can recognize voices.

- **Most students do not believe a computer can ever match a human in thought, action, and feeling.** They found feeling to be the most implausible. Many students agreed that computers might someday think and act humanlike, but not feel. One student wrote, "I completely disagree that you can make a robot be a human. You just can't. You can't

give a robot love from a mother." A large portion of students did express confidence that, although we do not yet have the ability to create humanlike computers, someday we will. Many students questioned the purpose of this enterprise altogether. "We probably could get pretty close [to creating a computer with human qualities], but I don't see the point." Further, some students argued this could lead to ethical problems. "Probably [we can create such a robot]. That will of course lead to issues about whether or not it is human. Plus how will we know it really feels emotions?"

- **Students were most likely to have learned about AI through the media or in school.** Through movies such as "AI," the entertainment industry is creating an image of artificial intelligence.

- **Computers are clearly a major part of these students' lives and it is through them that students see AI's effect.** Many students showed an awareness that AI has an impact on computer technology and that directly affects them.

- **Students saw AI as being both beneficial and harmful to humanity.** They reported that AI will help cut down on manual labor for humans and generally increase efficiency. "Computers and robots make our life so much easier." However, most students also realized this could lead to a shortage of jobs for humans. "They will cut down on the labor force." The media's impact also on this issue is also evident. A number of students noted that robots could eventually attack humans and take over the world. "You know, like in that movie AI."

- **Students noted that humans and computers have similar logic and information processing abilities.** Two examples mentioned were analysis and memory. However, one student said the manner of processing is vastly different. "Computers see either low or high current signals to continue … Humans see degrees of power and read the signals to know when to continue an activity."

- **Students had strong opinions that were about evenly split regarding harming a robot.** Some students said harming a robot would be an affront to the people who made the robot. Others said it would not matter because they are not humans. "They are not alive and they do not have feelings, like pain, etc." Still others noted that violence to a robot could preclude violence to a living being, such as another human.

Question 7: Explain how a robot works.

Response	*%*
Programming	40
Hardware/ Mechanical	19
Don't know	13
Computer chip	13
Brain	13

Question 8: Robots are one example of AI. Please list other examples.

Response	*%*
Computers	47
Home appliances	12
Other	11
Electronic Devices	9
Voice recognition	8
Video Computer games	5
GPS	5

Question 9: Some people think we can make a computer that thinks, acts, and feels just like a human does. What do you think?

Response	*%*
No	49
Maybe in the future	27
Yes	17

Question 10: Other than this survey, how have you learned about artificial intelligence?

Response	*%*
None	29
Media	29
Printed Media	13
Class	8
Family and Friends	8

Question 11: What ways does AI affect your life now? How could it in the future?

Response	*%*
Present	
Electronic Devices	8
Customer service answer service	5
Entertainment	4
Efficient manufacturing	4
Future	
Service	17
Exploration	4
Human deterioration	4

Question 12: How can AI be beneficial to people? How can it be harmful?

Response	*%*
Benefits	
Less work for humans and greater efficiency in everyday tasks	21
Exploration	12
Help people with disabilities	9
Harms	
Take jobs from humans	15
Attack humans and take over the world	12
Humans will become too lazy	11

Question 13: In what ways are computers and humans alike? In what ways are they different?

Response	*%*
Alike	
Intelligence	13
Storage of Information	13
Input/output	9
Knowledge	4
Work at a fast rate	3
Emotions	3
Different	
Emotions	35
Alive	13
Abstract (i.e. Consciousness, and Thinking)	9
Biological Functions	7
Versatility	3

Question 14: Would it be wrong to harm a robot? Explain.

Response	*%*
Yes	35
No	33
Situational	13
Don't know	9
Yes and no	8

Table 3: Student responses to questions 7-14 on the SSEP survey.

Table 4 shows the results of assessing each student's set of open-ended survey questions using the six-facets rubric developed by Wiggins and McTighe.[12] Below are some observations from assessing these facets

- **Explanation:** Most of the students who rated "sophisticated and comprehensive" reported learning about technology and, in some cases, AI in school. Most students rated "developed." Students often displayed creativity with regard to what AI could be in the future: for example, robots that could explore ocean depths or other parts of the natural world humans cannot access.

- **Interpretation:** Most students are at the "interpreted" level. This indicates they have learned about AI from school, movies, etc., and they have tried to make the information fit into their realm of understanding. For example, many students noted that AI can help them with their homework. They are trying to understand what AI means to their lives.

- **Application:** It is too much of a stretch to say that any students are masterful at answering these questions. The skilled students were able to make connections between AI theory and ethics. For example, some students questioned whether we should pursue AI that can feel. Most students displayed apprentice ability. They tried to make connections between what they know and what was being asked, but they generally fell short of true understanding.

- **Perspective:** It seems that for students at this age, it is common to believe what they learn and hear from adults. For example, students responding to the survey were generally "uncritical" of the information they have learned about AI. Further, they often did not consider alternative ideas or opinions.

- **Empathy:** The last survey question, regarding the ethics of harming a robot, revealed great empathy in student responses. They were often adept at considering the harm of hurting a robot. Regardless of their outcome, their answers revealed a clear thought process that involved "decentering."

- **Self-knowledge:** The students rated as "wise" to "thoughtful" revealed a thought process that questioned their own preconceptions. Often, this meant they were aware that Hollywood has a large impact on their understanding of AI. The remainder of the students did not question how they had formed their opinions or what factors impacted their opinions. Nonetheless, most students were "generally aware of what (they) do and do not understand."

Facet of Understanding	*Level of Understanding and Percentage of Student Responses at that Level*									
Explanation	Sophisticated, comprehensive	8	Systematic	12	In-depth	16	Developed	36	Naïve	28
Interpretation	Insightful	8	Revealing	8	Perceptive	19	Interpreted	39	Literal	27
Application	Masterful	0	Skilled	8	Able	24	Apprentice	48	Novice	20
Perspective	Insightful, coherent	0	Thorough	12	Considered	17	Aware	28	Uncritical	43
Empathy	Mature	12	Sensitive	23	Aware	16	Decentering	37	Egocentric	12
Self-knowledge	Wise	5	Circumspect	12	Thoughtful	49	Unreflective	25	Innocent	11

Table 4: SSEP student responses evaluated with the 6-Facet Rubric.[12]

IV. Discussion and Implications for the Classroom

JFK Data Set

Many of the students explored AI in a way that showcased their creative minds, but they struggled with the larger question being asked: what *is* AI? They often identified important issues such as emotion and intelligence, and several mentioned consciousness, thinking and perpetual learning. Many students held strong beliefs about these issues (e.g., a robot can never have feelings), but their ability to explain and justify these beliefs was often naïve and unsupported. Their difficulty in making more sophisticated and comprehensive explanations is not surprising since many of the AI issues that most engage learners (the possibilities of machine consciousness, ethical uses of technology, etc.) challenge people of all abilities and education levels. The implication for the classroom is that learners at this level are already often aware of and interested in many of the important issues related to AI. The challenge to teachers is to help them address their misconceptions and develop an increasingly sophisticated understanding.

Perhaps the most interesting aspect of the JFK data set is comparing the drawings and essays produced by girls and boys to see which features differ. Table 1 shows that girls and boys were equally likely to draw a robot with human-like qualities. However, boys tended to draw boxy robots with great attention to intricacies such as wiring and buttons (see Figure 2b-d). Their robots were often scary-looking with angry faces and jagged teeth. Like their drawings, the boys' essays also tended to portray a negative vision of AI. Many of their responses were patterned after movies: "Artificial intelligence is in movies a lot, like AI; I, Robot; and also Robocop. The movies are about robots starting to get smarter than the people who programmed them and then they start to try to kill people," claimed one boy. Another boy talked about a more grave fear, touching on issues of rebellion that we have seen throughout history, "I also think that robots will take over or rebel because if they can think independently they will find out if we misuse them and like any other thing that thinks, it won't be happy."

Girls' responses were markedly different. They were more likely to draw human-like robots with more rounded edges, careful detail, and smiling faces (see Figure 2e-g). The girls also focus more on the robot's function and how it served people. "My robot will do the laundry and give you a back rub," claimed one girl, while another stated "One of the functions of AI is to do things for humans. The Roomba, for instance, vacuums the room by itself. This saves humans time….computers and AI are designed to help humans." (One particularly insightful boy counteracted this argument of using AI for help stating, "I think that the idea of AI is useless. It just promotes laziness among humans, and eventually will erase the meaning of intelligence.") Although both boys and girls overwhelmingly drew robots, a significantly higher percentage of girls drew computers or other representations of AI, such as robotic cats, dinosaurs and plants for creating more oxygen. Only girls drew robots or representations with female features.

A greater focus of boys on technical details and aggressive behavior (see Figure 2c-d) and girls on functionality and service to society is hardly surprising. It is also consistent with the research on engaging girls in math and science. This research points to the importance of girls working on problems that they view as socially relevant and meaningful to them.[13] The implication for the classroom is that technical AI content learned in a socially relevant context can engage more learners.

Both boys and girls disagree with the notion of AI having emotion and mentioned this often in their essays. "I do not believe that a computer will have the capacity to love or hate or be happy. I say this because these are abstract things that someone can't put in a computers hard drive or software," claimed one student, while another addressed the idea of consciousness in his defense: "To me a machine is parts that are designed to do something specific. The machine can't be conscious because to be conscious you must be alive … A human can take a social cue or a cry of pain and help. A robot, however, could not distinguish cries and pain and joy … The main difference I think between humans and machines is feelings." The implication for the classroom is that this is a topic that evokes strong opinions in students making it a potential hook for engagement.

SSEP Data Set

The responses to the SSEP survey result in a number of implications for curriculum design and teaching. Even high academic achieving girls who overwhelmingly liked math, science and technology class (91%) and using computers (89%) are not as highly motivated to learn about AI (61%). Clearly in the typical classroom the percentage of girls who want to learn about AI will be lower. This highlights the need to provide powerful, thought-provoking hooks to initially engage and hold student interest. Fortunately, the field of AI is rich with possibilities that are both intriguing and can be related to technologies affecting student lives. For example, many students wrote passionately about the possibilities of a computer matching a human in thought, action and feelings or the ethics of harming a computer. They also repeatedly mentioned voice recognition software as an area of AI that affected and interested them. Ellis and Andam[6] found that in a high school course combining AI and philosophy, it was often the philosophical and ethical content of AI (made accessible through hands-on AI applications) that most consistently hooked students into learning about AI. They observed that this content appeared to have been the means for self-exploration at an age when students are trying to understand the essence of their own existence, identity and relationships with their peers. They report that this observation

is consistent with the research in adolescent development indicating the importance of a growing self-identity and introspection in adolescence.

Another implication of the survey is that although high school girls use technology constantly (73% reported that they were good at using computers, and their own use of various technologies such as cell phones were repeatedly cited in their responses), their understanding of how these technologies work is often unsophisticated. In spite of their strong academic credentials and reported interest in technology, only a few had a real understanding of how a robot works or a deep and multi-faceted understanding of AI. Nor could they support their strong opinions on computers being able to think, act or feel like a human. This phenomenon of sophisticated use of technology with little understanding of how it functions has been reported by a variety of sources. In *Technically Speaking*, the National Academy of Engineering (NAE) presents the importance of increasing technological literacy for all members of our society. They point out that achieving this literacy depends on a more holistic understanding of the content areas involved in technology.[14] This shows the need not only for designing robots and writing programs, but also for helping students to think differently about technology and to fundamentally question how AI meets society's needs. Such an approach is consistent with the research pointing to social relevance as a key ingredient for engaging girls.

Finally, it is interesting to note that students most often mentioned the media—particularly television and movies—as where they had learned about AI. Given the power of the medium, the potential for developing misconceptions is great (although it is notable that students often questioned the reliability of these sources). If not addressed, these misconceptions might result in new information seeming incomprehensible to the learner or the development of representations of the new information that include deep misunderstandings. To remedy this, teachers need to make their students' thinking move visible and provide opportunities to help them reconceptualize their faulty conceptions.[1]

V. Conclusions

Two data sets were collected to evaluate the preconceptions of pre-college students about AI with the purpose of enhancing engagement and learning. The first data set, consisting of middle school students, showed that students most often viewed AI as a robot or computer and generally expressed a positive vision of AI. They also tended to believe that AI systems cannot have emotions or feelings. Gender differences were seen in how they illustrated and wrote about AI. The boys' vision of AI tended to focus more on technical details and aggressive behavior, while the girls' vision was generally more positive and focused more on how AI could serve humanity.

The second data set consisted of high school girls participating in a summer science and engineering program. It showed that even these girls who were highly motivated to study science and engineering were not as motivated to learn about AI. They wrote passionately about a number of controversial topics in AI—possibly indicating issues that could be used to increase engagement. Although many of the respondents were facile with the use of a variety of technologies in their personal lives, few had a real understanding of the field of AI. As was the case with the middle school students, the media played a powerful role in shaping the students' knowledge of AI.

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VII. References

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