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Development of an Assessment for Measuring Middle School Student Attitudes towards Robotics Activities

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***Abstract*— The next generation of world citizens must be technologically fluent members of society. By technological fluency we mean the ability to manipulate technology creatively and for one's own use. This fluency is composed of knowledge and skills utilizing materials and tools, as well as attitudes, (e.g. confidence), with respect to technology. Numerous interventions exist to support middle school students' technological fluency, and robotics activities are popular. It is critical that instruments assessing student attitudes towards robotics are available for the development and evaluation of these interventions.**

We present an instrument for assessing middle school students' technological fluency attitudes specifically tailored for robotics activities. Survey subscales were developed from existing science motivation research, and individual measurement items were generated and adapted within those subscales. The robotics activity attitudes scale (RAAS) was revised through three rounds of pilot testing in 2010, 2012 and 2015. The final RAAS in 2015 consisted of 50 items with an overall Cronbach's alpha of .972 (N=236) organized in four dimensions of Curiosity, Interest, Expectancy Value, and Confidence and Identity.

Keywords*— *assessment tools; middle school; technological fluency; educational robotics

I. INTRODUCTION

It is extremely important that the next generation of world citizens be technologically fluent members of society; one must be able to manipulate technology creatively and for one's own use. Technological fluency, when compared with technological literacy, is the capacity to be a creator of new tools and solutions, and not merely a competent user of available tools. Technological fluency, which includes skills and knowledge regarding tools and materials, in addition to attitudes, such as confidence, with respect to technology, is crucial for students engaging in both engineering and computer science [1] [2]. Numerous extracurricular and in-school interventions are being developed and are in use with goals related to the support of middle school students' technological fluency in order to meet the needs of 21st century learners. Robotics activities are a popular vehicle for this type of instruction [1] [3]. It is critical that instruments assessing student technological fluency are available for the development and evaluation of these educational robotics interventions. In this paper we present an instrument designed for assessing middle school student attitudes towards robotics.

During our preliminary work on the development of the extracurricular craft-based robotics program, Arts & Bots, (also referred to as Robot Diaries), our evaluations of student technological fluency were divided into three categories: confidence and interest with respect to technology, technology knowledge, and creativity with robotics [2]. Following the initial development of the Arts & Bots program through participatory design sessions, the research team collected data through qualitative and quantitative methods including: workshop observations, pre/post interviews of students, pre/post surveys, interviews of parents and teachers, and evaluated hands-on debugging and creative design tasks [4] [2].

Following this mixed methods extracurricular evaluation, the Arts & Bots program was transitioned to in-school environments to address concerns about participant self-selection bias in the extracurricular pilot (Figure 1). The increased number of participants shifted our evaluation focus to

Fig. 1: Students participating in Arts & Bots combine robotic hardware, computer programming, and crafts to create robotic sculptures tied to class curricular goals, such as this scene from Romeo and Juliet created by students in eighth grade English class.

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emphasize student surveys and limited the number of interviews and one-on-one task evaluations due to practical expansion considerations. We then began the development of student surveys, consisting of two components: attitudes with respect to technology which included confidence, interest, and creativity; and knowledge with respect to technology, which were distilled from the three technological fluency habits of mind and informed by earlier qualitative and quantitative results. In the context of robotics activities and this particular assessment, we define technology specifically as equipment that is computational or robotic, as matches the colloquial usage of middle school students.

II. Development Method

It is the ultimate goal of our work to develop a valid and reliable tool for evaluating attitudes with respect to technology and knowledge with respect to technology. Validity and reliability are interrelated but separate properties of measurement [5] [6]. The reliability of a measurement reflects the "permanent effects that persist from sample to sample," and is inclusive of both the stability of a subject's of scores over time and the internal consistency of items [6]. The validity of a measure refers to how well it actually measures the intended construct [6]. In this development, our work was informed by the process for developing valid and reliable scales for evaluating psychological constructs recommended by Netemeyer, Bearden and Sharma [6]. This process takes a four step approach:

1. Construct Definition and Content Domain
2. Generating and Judging Measurement Items
3. Designing and Conducting Studies to Develop and Refine the Scale
4. Finalizing the Scale

Since the goals and instruction of technological fluency as developed in robotics programs is deeply influenced by the hardware system used and the focus of the activity, our focus in this paper is on the development of the attitudes assessment scale which is more widely applicable and generalizable for similar robotics programs regardless of the system used. We present in this paper our development process thus far of that student attitude scale, along with our initial construct definitions and the items we generated to measure this in our early work in 2010. We then present the analysis and refinement that we performed on this scale following an initial study from 2010 to 2012. Data collected during this initial study was then used to inform further refinements for a revised version of the survey in 2012. Data was collected using this scale during a 2012 to 2014 study. The most recent version of this survey was developed following further analysis in 2015. Finally, we present our early results from data collected using this 2015 version of the scale.

III. Construct Definition and Related Works

Our goal in creating our Robotics Activities Attitudes Scale (RAAS) was to provide extracurricular and in school robotics programs a means for evaluating the effectiveness of the program in improving middle school student attitudes towards robotics. Despite the overarching intent of these robotics programs to improve student Technological Fluency, we focused more specifically on the evaluation of students attitudes towards robotics activities for two main reasons. First, we believe that changes in attitudes towards robotics are the first sign of preparing a student for continued motivation, participation, and interest in robotics and, more broadly, STEM activities. Second, we expect that short duration interdisciplinary activities will have measurable impacts on student localized attitudes toward robotics. However, more generalized student attitudes towards technology, as a component of Technological Fluency, are slow to change and will need repeated engagement over time to become large enough to be measurable. It is important to enable the measurement of localized attitude changes towards robotics occurring early in the program in order to inform the development and refinement of program instruction. By providing this formative feedback to robotics programs, it is possible to check progress towards the prevalent program goal of attracting students to participate in STEM.

TABLE I. Definitions of the Hypothesized Dimensions of Student Attitudes towards Robotics with Sources

Dimension	Definition	Sources
Interest	A student's positive feelings towards robotics activities and positive affect about robotics and technology more generally.	[13] [14]
Expectancy Value	A combination of a student's expectancy and value of robotics tasks, this includes highly valuing robotics tasks and having confidence in one's own ability to successfully complete that task.	[13] [14]
Curiousity	A student's motivation to seek understanding about robotics and technology, investigate new ideas, and excitement towards learning about new concepts involved in robotics and technology.	[13] [14]
Confidence	A student's confidence in using technological tools and in completing robotics tasks, i.e. how well a student believes they can complete a robotics project.	[15]
Behavior	A student's intentions of participating in robotics and technology activities in the future.	[16] [17]
Relevance and Perceived Value	A student's belief that the robotics activities have value in and relevance to everyday life.	[16]
Social Motivation	A student's motivation related to their desire to use robotics to help people and society.	Hypothe-sized, original scale

During the development of our creative robotics program, Arts & Bots, [7] [8] investigation of related works did not uncover a validated scale for assessing student attitudes for robotics activities; however, scales existed for a variety of related constructs such as attitudes towards engineering, motivation toward science, and attitudes towards robots. Notice that the focus of the RAAS is attitudes towards robotics activities, specifically the creation and development of robots as a subset of technological fluency. This is distinguished from existing scales for evaluating attitudes towards robots [9] [10], which focus on a person's attitudes towards robots, as a consumer of completed devices.

A number of scales have also been created for accessing student attitudes towards engineering. Besterfield - Sacre [11] developed one such scale measuring undergraduate attitudes towards engineering. This scale included measures of both student attitudes and student self-assessments in engineering. Some engineering attitudes scales were also developed for middle school students [12]. While these were closely related to the tool that we sought to develop, the focus on general engineering was overly broad for our focus on robotics programs. Their scales for attitudes towards engineering included: interest (both in stereotypical and non-stereotypical aspects of engineering), positive opinions, negative opinions, problem solving, technical skills, and additional items.

Finally, Bathgate and colleagues, from the Learning Activation Lab, [13] [14] developed a tool for assessing student motivation in science. They associate the concept of student motivation in STEM as being a critical component in a student's future engagement and participation in science and STEM. The 89 items of their scales were distributed between dimensions of context (formal or informal), manner of interaction, science topic, and the motivation dimensions. They defined motivation towards science as having the following dimensions: appreciation, curiosity, identity, interest, persistence, responsibility, and expectancy value. This, as it most closely invokes our interests, was the basis for many of our scales for attitudes towards robotics activities.

From this related research, we hypothesized seven base scale definitions that represent the dimensions of student attitudes towards robotics: Interest, Expectancy Value, Curiosity, Confidence, Behavior, Relevance and Perceived Value, and Social Motivation. Please refer to Table I for the definitions of these dimensions and the item sources used for each dimension.

IV. Generating Measurement Items for RAAS

For our seven dimensions of student attitudes towards technology, items forming the interest, expectancy value, and curiosity scales were primarily adapted from the "Activated Science Learner: Technical Report for Surveys 1.1-5.0" [14]. This was a precursor to Bathgate 2014 [13], which provides items, evaluating attitudes of six science topics: astronomy, biology, earth science, engineering, physical science, and general science. These items were adapted from the science topics to align with our focus on robotics and technology. Terms related to other topics were modified to read: robots, robotics, technology, and computers. We choose to include questions related to technology and computers, to provide greater variety between items to reduce response fatigue, we considered technology and computers to be closely related to robotics activities as most such activities include tasks and elements on a computer. The confidence scale utilized some items from a scale developed to evaluate perception of oneself as a computer user which were adapted to reference robots [15] [2].

The final attitudes scale had questions that were distributed among dimensions as follows: interest (12 items), expectancy value (10 items), curiosity (8 items), confidence (3 items), behavior (3 items), perceived value and relevance (5 items), social motivation (2 items), and other (1 item). Table II lists all of the items that are in each dimension used in the 2010 version of the RAAS. The items were constructed as 44 Likert-like scale items where students stated their agreement with various statements on scale consisting of "NO!", "no", "neither yes or no", "yes", and "YES!" [12] which we scored with a 1 to 5 scoring where 1 was "NO!" and 5 was "YES!".

V. Piloting RAAS 2010

During the 2010/2011 and 2011/2012 academic years, three teachers implemented our robotics program, Arts & Bots, with their classes, collecting survey data using RASS 2010 both pre and post project. The first teacher had 30 students in a technology class complete the pre-test survey in November 2010 and the post-test survey in May 2011. The second teacher had 15 students in a history class complete the pre-test survey in February 2011 and the post-test survey in March 2011. The third teacher had 10 students in an anatomy class complete the pre-test survey in December 2011 and the post-test survey in January 2012. The classes provided pilot evaluation data for a total of 56 students. To avoid double counting, we limited analysis results from the students' pre surveys. Student agreement responses to each item recoded to be as score from 1 to 5 was used in our analysis of the scales. Negatively worded items were recoded in reverse, 5 representing the strong disagreement of "NO!".

In order to construct dimensions with internal reliability, we first evaluated the Cronbach's Alpha of each sub-scale. The shorter of the item sub-scales (Confidence, Behavior, Social Motivation, and Perceived Value) did not have enough items to test for internal reliability. The Expectancy Value scale had an acceptable Cronbach's Alpha of .764 with 10 items. This scale included the question "I'm afraid I won't be able to do a good job on a project about computers" that had a notable negative impact on the reliability, and if removed, the Cronbach's alpha jumped to .799. This indicated a poor match between this item and the rest of the scale, which we suspect was caused by the confusing wording of the question with two negative words "afraid" and "won't". The Interest subscale had an excellent Cronbach's Alpha of .860 with 12 items. The Curiosity subscale had a excellent Cronbach's Alpha of .871 with 8 items.

We also performed an exploratory factor analysis on the three larger dimensions (Curiosity, Interest, and Expectancy Value) to test if the scales developed were univariate. Reversed or negative items were excluded from this analysis because their own factors are frequently formed.Exploratory Factor Analysis was performed using SPSS using the Maximum Likelihood fitting procedure and Promax oblique rotation method.

From the Expectancy Value subscale, three factors were extracted using an eigenvalue threshold of 1 and checking the Scree plot for additional relevant factors. The first two factors accounted for 56.1% of variance of the scale and had weighting that cleanly divided the items between items that used the word "robotics" or "robots" as the subject and those that used the word "computer." The item "I ask a lot of questions about computers if I don't understand them" was the only item in the third factor.

TABLE II. ITEMS INCLUDED IN THE RAAS 2010

Sub-Scale	Item
Interest	1. I would like to learn more about robots.
	2. Computers are interesting to me.
	3. Topics like robots just don't grab my interest.
	4. Robots are interesting to me.
	5. I use the Internet to find information about computers.
	6. I like to watch TV shows and/or read about robots.
	7. I try to do activities related to computers.
	8. I like to explore computers.
	9. I like to do robotics activities.
	10. I feel good when I learn about computers.
	11. Robots are boring to me.
	12. I have a good feeling about computers.
Expectancy Value	1. I want to learn everything about computers, even if it is complicated
	2. Learning about robots is important to me.
	3. I know I can learn a lot about robots.
	4. If I started a robotics project, I think I could do a really good job.
	5. I'm afraid I won't be able to do a good job on a project about computers.
	6. It's important to me to know more about computers than most people.
	7. When I don't know something about computers, I try and find an answer.
	8. I ask a lot of questions about computers if I don't understand them.
	9. I like to prove that I know more about robots than my friends.
	10. I like to learn new facts about robots.

TABLE II. INCLUDED IN THE RAAS 2010 (CONTINUED)

Sub-Scale	Item
Curiousity	1. I am curious about robots.
	2. I am interested in discovering things about computers.
	3. I get excited about discussing computers.
	4. It is cool to learn new things about robots.
	5. I enjoy exploring new ideas about computers.
	6. I look for as much information as I can about robots.
	7. Everywhere I go, I am out looking for new things about robots.
	8. I am often trying to find out more about computers.
Confidence	1. I feel confident about my ability to make robots.
	2. I am the kind of person who is good at making robots.
	3. I am not good at making robots.
Behavior	1. I plan to take more robotics or computer classes at school.
	2. I plan to sign up for robotics or computer activities outside of school.
	3. I plan to build my own robot.
Relevance and Perceived Value	1. Robots have nothing to do with my life outside of school.
	2. Learning about robots will help me understand how everyday things work.
	3. Learning about computers is not important for my future success.
	4. Most people should learn about robots.
	5. It is important to know about computers in order to get a good job.
Other	1. I wish I had robot-building materials at home.
Social Motivation	1. I want to help other people understand computers.
	2. I want to use robots to help solve people's problems.

The items of the Curiosity dimension split into two factors accounting for 65.8% of variance. The two factors again split the four "robot" items from the four "computer" items. We also see this trend in the Interest dimension, which divided into two factors accounting for 59.2% of variance, one containing four "robot" and the other containing six "computer" questions.

VI. CREATION OF RAAS 2012

Our piloting of the RAAS 2010 highlighted two major areas for revision:

1. We saw that it was not feasible to test scale reliability using Cronbach's alpha on the scales that have 5 or fewer items, notably: Confidence, Behavior, Social Motivation, and Perceived Value and thus we could not generate generalizable conclusions for the cumulative scores, on these scales. We reformulated and combined these domains to create the new "Confidence and Identity" dimension comprised of nine items.
2. We saw that all three of our factors with more than five items, (Expectancy Value, Interest, and Curiosity), were not univariate and instead produced at least two factors each through exploratory factor analysis. The items which had been adapted to have "robots" or "robotics" as the item topic formed one factor within each dimension; those adapted to include the word "computer" formed a second factor. This prompted a refinement of the wording choices for how we adapted the items from the original sources.

Looking back at the items as developed by Bathgate and colleagues [13], we noticed that we had failed to take into account the hierarchy or generality of the topic of each item. We hypothesized that this played an important role in how our dimensions were interpreted by students. Further, we realized that our items may be suffering from an expert blind spot where we, as robotics researchers and educators, are prone to seeing the inherent relationship and connection between robotics and computers. Students piloting our survey clearly demonstrated internal, conceptual separations of robots and computers.

We then reviewed each source item in its original form in order to better match the source items in terms of level of abstraction. In this way, we matched highly abstract and general concepts like "science" to "technology", more specific ideas of a discipline like "biology" to "robotics", and very concrete topics such as "animals" to "robots." We also removed items that either negatively impacted the Cronbach's alpha or contributed very little, in order to reduce the overall length of RAAS. As seen in Table III, the resulting modified subscales for attitudes towards robotics activities, RAAS 2012, consisted of four balanced-length sub-scales, reduced the number of Likert-

TABLE III. ITEMS INCLUDED IN THE RAAS 2012

Sub-Scale	Item
Interest	1. I would like to learn more about robotics.
	2. Technology is interesting to me.
	3. Robotics is interesting to me.
	4. I like to watch TV shows and/or read about robots.
	5. I try to do activities related to technology.
	6. I like to do robotics activities.
	7. I feel good when I learn about technology.
	8. Robots are boring to me.
	9. I have a good feeling about computers.
Expectancy Value	1. I want to learn everything about technology, even if it's complicated.
	2. Learning about robots is important to me.
	3. I know I can learn a lot about robots.
	4. If I started a robotics project, I think I could do a really good job.
	5. It's important to me to know more about technology than most people.
	6. When I don't know something about computers, I try and find an answer.
	7. I ask a lot of questions about robots if I don't understand them.
	8. I like to prove that I know more about technology than my friends.
	9. I like to learn new facts about robots.
Curiousity	1. I am curious about how robots work.
	2. I am interested in discovering things about robots.
	3. I get excited about discussing technology.
	4. It is cool to learn new things about robots.
	5. I enjoy exploring new ideas about robotics.
	6. I look for as much information as I can about robots.
	7. Everywhere I go, I am out looking for new things about robots.
	8. I am often trying to find out more about computers.
Confidence and Identity	1. I feel confident about my ability to make robots.
	2. I am the kind of person who works well with technology.
	3. I am not good at making robots.
	4. Whenever I use something that is computerized, I am afraid I will break it.
	5. I feel uncomfortable when someone talks to me about technology.
	6. I am a technical type person.
	7. Other people think of me as a technical type person.
	8. It makes me nervous to even think about using computers.
	9. I am the type of person who could become a roboticist.

type items from 44 to 36, and reduced the number of computer-specific questions from 15 to the 5.

VII. PILOTING RAAS 2012

Between 2012 and 2014, nine additional seventh and eighth grade classes taught by six teachers participated in our robotics program Arts & Bots. Students in these classes took the RAAS 2012 both before and after their projects. In order to avoid double counting students, we only used the students' pre survey data in this analysis. Within these nine classes, we collected data from 159 pre surveys completed by students.

TABLE IV. FACTORS FROM RAAS 2012 EXPLORATORY FACTOR ANALYSIS

Factor Description	Example Items	Variance
Personal Robotics Identity	Everywhere I go, I am out looking for new things about robots.	6.4%
	I am the type of person who could become a roboticist.	
Interest in Learning about Robotics	It is cool to learn new things about robots.	52.2%
	Robotics is interesting to me.	
Interest in Learning about Technology	I am often trying to find out more about computers.	5.2%
	I get excited about discussing technology.	
Confidence with Technology	It makes me nervous to even think about using computers. (negative)	3.7%
	I have a good feeling about computers.	

Using the data from the 2012 to 2014 pilot, we again evaluated the internal consistency of the scales using Cronbach's alpha. The 8 item scale for Curiosity had an alpha of .926 reflecting excellent internal consistency. The 9 item Interest scale had excellent internal consistency with Cronbach's alpha equal to .929. The 9 item Confidence scale had good internal consistency and Cronbach's alpha of .846. Finally, the Expectancy Value scale had 9 items and an alpha of .891.

We also performed an exploratory factor analysis on the complete 35 item scale to explore how items correlated with one another compared to our four expected dimensions. This Exploratory Factor Analysis was performed using SPSS using the Maximum Likelihood fitting procedure and Promax oblique rotation method. We extracted factors based on an eigenvalue threshold of 1 and checking the Scree plot for additional relevant factors. Using these methods, we identified four factors that accounted for 67.5% of scale variance. However, these factors were not explicitly divided into the dimensions that we hypothesized. Instead we found the following four factors: Personal Robotics Identity, Interest in Learning about Robotics Interest in Learning about Technology, and Confidence with Technology. These factors are described in Table IV with example items. We used these factors to help inform the creation and removal of items to create the RAAS 2015.

VIII. CREATION OF RAAS 2015

Our analysis of the RAAS 2012 scale primarily highlighted problems with the Confidence and Identity scale as well as issues with how secondary dimensions were distributed. While the four main constructs of RAAS 2012 were Curiosity, Expectancy Value, Interest, and Confidence and Identity; secondary item features such as subject (technology versus robotics versus robots) and negative structure (i.e. reversed items) were non-uniformly distributed among the primary

TABLE V. ITEM ADDED TO THE 2012 RAAS TO CREATE THE 2015 RAAS

Activity Aspect	New Items
Programming Confidence	Capacity: "I can write a computer program"
	Capacity: "I can program a robot"
	Future: "I could learn to write a computer program"
Robot Building Confidence	Capacity: "I can make a robot"
	Skill: "I could learn to build a robot"
	Future: "I could learn to build a robot"
Engineering Design	Skill: "I am good at designing things"
	Appreciation: "I come up with solutions that other people don't think of"
	Enjoyment: "I like designing new things"
Computational Thinking	Skill: "I am good at thinking logically"
	Application: "I solve problems logically"
	Enjoyment: "I like solving complex problems"
Teamwork	Skill: "I am a good team member"
	Capacity: "I can communicate my ideas to my team"
	Enjoyment: "I like working on teams"

dimensions and were influential in how items were grouped in our exploratory factor analysis. The subjects of the 35 RAAS 2012 items were: 8 robots, 5 computer, 11 robotics, and 11 technology. Five items were reversed.

The 9 items in the Identity and Confidence scale were disproportionately negative (i.e. 4 of the 5 negative items in the RAAS 2012 were Identity and Confidence items), and a disproportionate number of the items had general technology or computers as the subjects (i.e., only 3 items had robotics or robots as the subject).

We saw the impact of this in the Exploratory Factor Analysis of the 35 items, which presented four factors: Personal Robotics Identity, Interest in Learning about Robotics, Interest in Learning about Technology, and Confidence with Technology. The complementary factors of Interest in Learning about Robotics and Interest in Learning about Technology drew attention to the interrelationship between our Curiosity and Interest constructs and again highlighted the distinction between "robotics" and "technology and computers" as conceptualized by middle school students. This was the same conceptual distinction that we saw on the RAAS 2010. However the Confidence with Technology factor did not have a complementary Confidence with Robotics factor, which prompted us to work to strengthen and balance the Confidence and Identity scale with additional items with robots or robotics as the subject.

We also found that nearly all of the items that were associated with robots and robotics were generalized, such as "Robotics is interesting to me", and did not mention the specific activities involved in robotics projects. We systematically generated new items related to five aspects of robotics activities: Programming, Robot Building, Computational Thinking, Engineering Design Process, and Teamwork. Within these aspects we generated five types of items: Capacity where students assessed their ability to complete an action, Skill where students evaluated the quality of their skills, Application where students rated if they perform certain actions, Enjoyment where students rated their enjoyment of the action, and Future where students assessed their ability to learn to do the action. The Capacity, Application, Future, and Skill items were all created to strengthen the Confidence and Identity dimension. The Enjoyment items were added to with the Interest dimension. The Teamwork aspect items were not included in the Confidence and Identity and Interest dimensions, as they were on the separate subject of teamwork and not technology or robotics.

IX. PILOTING RAAS 2015

In 2015 and 2016, ten classes taught by ten teachers participated Arts & Bots. Students in these classes took the RAAS 2015 both before and after their projects. In order to avoid double counting students, we only analyzed the students' pre survey data. From these 10 classes, we collected data from 242 student pre surveys. Six students did not complete all the sections of the survey and so their data is excluded when items they missed were part of the analysis. The Teamwork items were not included in the scale analysis as they were not part of the four main construct domains.

Using the data from the 2015 to 2016 study, we again evaluated the internal consistency of the scales using Cronbach's alpha. The 8 item scale for Curiosity had an alpha of .918 reflecting excellent internal consistency. The 11 item Interest scale also had excellent internal consistency with a Cronbach's alpha equal to .921. The 19 item Confidence scale had an excellent internal consistency and a Cronbach's alpha of .918. Finally the Expectancy Value scale had 9 items and a good alpha of .879.

We performed an exploratory factor analysis on the RAAS 2015. We excluded reversed or negative items as they frequently form their own factors. We also excluded the teamwork items which are related to a completely separate aspect of robotics activities. Exploratory Factor Analysis was performed using SPSS using the Maximum Likelihood fitting procedure and Promax oblique rotation method. We extracted 5 factors following the guidelines of using an eigenvalue threshold of 1 and evaluating the Scree plot, which accounted for 66.2% of scale variance. The 5 factors were: Confidence, Learning Potential, Personal Robotics Identity, Personal Technology Identity, and Curiosity.

Two of the factors that we extracted matched dimensions that we had constructed. The Confidence factor included items encompassing confidence related to skills involving robots, computers, and problem solving (see Table VI). The Curiosity factor included items that measured a student's affect towards discovering, exploring, and learning about new robotics and technology concepts.

Two other factors were related to the student's personal identity. The Personal Robotics Identity factor included interest, identity, expectancy value, and strongly worded curiosity items that reflected the broader importance of robotics to everyday life. Similarly, the Personal Technology Identity factor included interest, identity, curiosity, and expectancy value items that

TABLE VI. RAAS 2015 FACTORS

Factor	Item
Confidence	1. I am good at making robots.
	2. I can program a robot.
	3. I can write a computer program.
	4. I can make a robot.
	5. I am good at thinking logically.
	6. I feel confident about my ability to make robots.
	7. I like solving complex problems.
	8. I am good at designing things.
	9. I solve problems logically.
	10. I could learn to write a computer program.
Learning Potential	1. If I started a robotics project, I think I could do a really good job.
	2. I could learn to build a robot.
	3. I like designing new things.
	4. I would like to learn more about robotics.
	5. I feel good when I learn about technology.
	6. I like to learn new facts about robots.
	7. I get excited about discussing technology.
	8. I like to do robotics activities.
	9. I know I can learn a lot about robots.
	10. I ask a lot of questions about robots if I don't understand them.
Personal Robotics Identity	1. Other people think of me as a technical type person.
	2. I try to do activities related to technology.
	3. I am a technical type person.
	4. When I don't know something about computers, I try and find an answer.
	5. I am often trying to find out more about computers.
	6. I am the kind of person who works well with technology.
	7. I like to think that I know more about technology than my friends.
	8. Technology is interesting to me.
	9. I have a good feeling about computers.
	10. I come up with solutions that other people don't think of.
Personal Technology Identity	1. Everywhere I go, I am out looking for new things about robots.
	2. I like to watch TV shows and/or read about robots.
	3. I am the type of person who could become a roboticist.
	4. I look for as much information as I can about robots.
	5. Learning about robots is important is important to me.
	6. It's important to me to know more about technology than most people.
Curiosity	1. It is cool to learn new things about robots.
	2. I am curious about how robots work.
	3. I enjoy exploring new ideas about robotics.
	4. Robotics is interesting to me.
	5. I am interested in discovering things about robots.
	6. I want to learn everything about technology, even if it's complicated.

measured the broader importance of technology and computers to everyday life.

The final factor was very interesting in that it included interest, confidence, curiosity, and expectancy value items that measured a student's confidence in their ability to and positive feelings towards developing skills and gaining knowledge with respect to robotics and technology. This factor is unique from the dimensions that we originally developed for RAAS 2010, but also very interesting. Other education research has demonstrated that the belief that intelligence is malleable, sometime referred to as having a Growth Mindset, has positive implications for student motivation and resilience [18] [19].

X. FUTURE DIRECTIONS

The internal consistency and exploratory factor analysis of RAAS 2015 indicate that the assessment tool that we have developed provides insight into understanding the attitudes that middle school students have towards robotics activities. Future directions for the refinement of the tool include removing items that correlate to more than one dimension from the RAAS 2015 in order to create easier to score and distinct final scales, while reducing overall length. It may be possible to further shorten and refine the tool by investigating inter-item correlation and removing those highly correlated items that do not contribute additional information about student attitudes.

While our pilots show that RAAS is sufficiently reliable, RAAS should also be validated through Confirmatory Factor Analysis (CFA) in order to evaluate the final fit that our hypothesized model has with the study data. It will be possible to complete this CFA using post-test data as our analysis so far has only made use of pre-test data. Further validation may be conducted to test for score stability through ensuring that the student scores remain consistent over time. We may also choose to run known-group validity testing in which scores from groups of students expected to score high and low on the scale, based on other evaluations such as interviews and observations of student attitudes toward robotics, are compared to ensure that the scale detects the intended differences.

Lastly, as we continue to use RAAS with an increasingly large population, we could provide data on expected scores for middle school student populations, allowing other researchers to compare our baseline distributions for student scoring on the scale with their own program participants.

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