Inspiring Australian secondary school students through the Science Bootcamp program

Abstract

For Australia to maintain its flourishing economy and international competitiveness, more of its youth must pursue education and careers in science, technology, engineering, and math (STEM). Our project aimed to increase student interest in STEM by creating two activities for the Commonwealth Scientific and Industrial Research Organisation (CSIRO) Science Bootcamp program. These activities, a build-your-own electrocardiogram (ECG) and a spacecraft prototyping project, will provide students with a four-hour building and testing experience. These activities were informed by our research into science enrichment programs, by our analysis of past Bootcamp assessment data, and by an iterative development process.

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An uncertain future: Australia's youth are losing interest in STEM fields

Without innovators to generate new ideas, and without Science, Technology, Engineering, & Math (STEM) workers to realize those ideas, a nation is at risk of being left behind in the march of technological progress. Today, Australia and many other developed nations' youth are not pursuing STEM fields.[1] Many Australian politicians and business leaders worry that a lack of qualified STEM professionals will limit Australia's research capabilities and seriously hinder economic growth. Australia's Chief Scientist has voiced concern about this issue after his office reported that "seventy-five per cent of the fastest growing occupations now require STEM skills and knowledge," and yet, some employers have difficulty finding new hires for STEM positions.[1] The Office of the Chief Scientist found that of several hundred employers surveyed, 40% reported difficulty in filling technician roles, and 31% noted difficulty with hiring enough STEM graduates.[2]

The lack of candidates seeking jobs in STEM may originate from a growing disinterest in science and math among primary and secondary school students, who increasingly choose not to study or pursue careers in STEM fields. While the total number of students in the 12th year of Australian schooling has increased by 12% from 1992 to 2012, the participation rates for most elective math and science courses have fallen, some by as much as 10%.[3] Furthermore, according to the Programme for International Student Assessment (PISA) testing from the Organisation for Economic Co-operation and Development (OECD), Australian students' mathematics literacy rates have declined since 2000. Although Australia still ranks among the top nations (14th overall for mathematics), countries with similar PISA mathematics average scores in 2000, such as Canada and Switzerland, have experienced a rise in scores since then, making Australia's decline especially troubling. In Figure 1, Australia's mathematics literacy scores are compared to a top performing country (Hong Kong), other similarly performing nations, and the OECD average score over time. As shown, Australia's scores are declining faster than the OECD average.

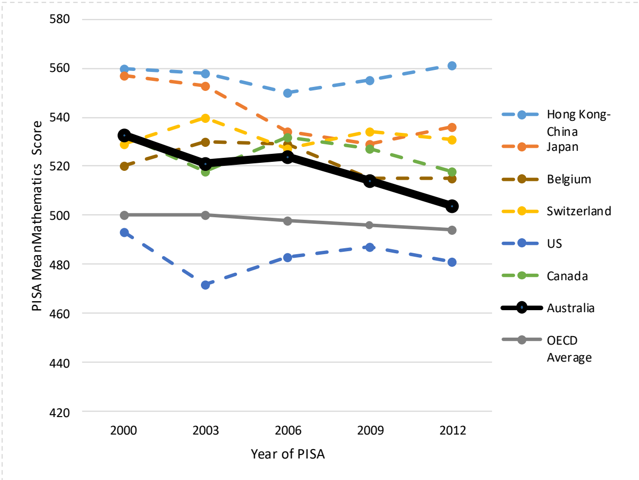


Figure 1. Australian math literacy levels

In Australia, the Commonwealth Scientific and Industrial Research Organisation (CSIRO) is attempting to reverse this negative trend in performance and interest in STEM. As a leading scientific research agency, CSIRO is heavily invested in promoting science and industry throughout Australia, offering numerous programs to promote greater student involvement in STEM. These initiatives range from training teachers to implement hands-on learning in classrooms, to producing a television program that shows children how science can be fun and relevant. In an effort to expand their outreach, CSIRO has implemented a Science Bootcamp to encourage more students to enter STEM fields.

Typically held during school holidays in major cities, secondary school students, age 13 to 18, visit CSIRO campuses over a two-day period, touring laboratories, attending presentations, and completing fun science activities. After two years with over 300 student attendees, CSIRO would like to assess which activities, topics, and interactions students most value in these Science Bootcamps. This information can be used to develop effective Bootcamp activities in the future.

The goal of our project was to help CSIRO increase youth interest in STEM through its Science Bootcamps. This goal was achieved through three objectives: (1) reviewing best practices in STEM education, especially the use of hands-on activities to increase student interest; (2) analyzing existing evaluation data on previous Science Bootcamp activities; and (3) using this information to conceptualize, test, and refine a new set of activities for future Science Bootcamps (Figure 2).

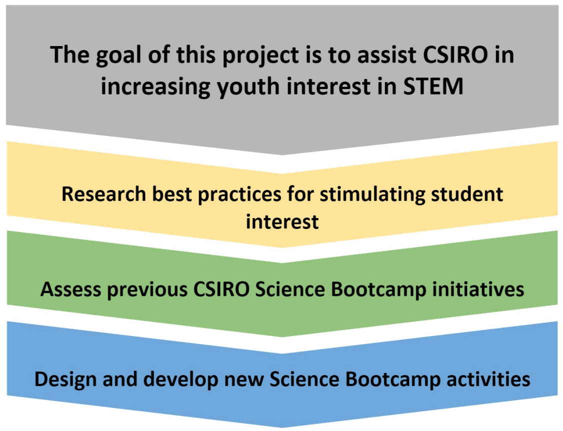


Figure 2. Project goal and supporting objectives

How to motivate students in STEM Fields

Many enrichment programs have been created with the goal of raising and maintaining students' interest in STEM. Each of these programs utilizes a unique method to motivate students to pursue STEM fields.

Defining student motivation, interest and engagement

Increasing motivation, or the drive someone has to do something, is the end goal of most enrichment programs. When there's little time to teach a student about a subject, the magnitude of an educator's impact can be measured not only in facts and figures students have absorbed, but also in the student's increased motivation to pursue that subject later. Motivation is, in our case, what drives the student to pursue certain academic and professional paths. It is an important construct in psychology, and many experts have outlined effective methods for motivating individuals, especially with the intention of driving long-term impacts. However, motivating students and measuring this impact can often take impractical lengths of time. It can take months or even years to influence a student's motivation, and just as long to test for changes in motivation.[5]

Motivation is interrelated with two other constructs of educational psychology, however, that are easier to achieve and measure: engagement and interest. Engagement is how attentive and involved a student is in the moment of a lesson or activity. Because engagement is defined at a given time, rather than over a span of time, a student's level of engagement can be determined by observing them for a short duration.[6] While this is advantageous for short term programs, a student's level of engagement is often a poor indicator of long-term motivation.[6] Interest is a much better indicator. Interest is how much a student cares about the subject. Interest can be sparked by one well-developed class or activity, or it can be instilled over multiple activities on the topic. One researcher, Deci, has shown that interest can be measured with simple short term surveys--an ideal approach for a short-term program, such as the Science Bootcamps.[6] Because this construct is developed in a shorter time frame than motivation, but can have more enduring effects than engagement, it is a primary focus of our bootcamp design. These constructs are further compared in Table 1.

A study by Linnenbrink-Garcia et al. recognized two major categories of student interest: individual and situational interest. They define individual interest as how much one inherently cares about a subject and situational interest as how much an individual cares about a subject at a particular time. If an instructor maintains a student's situational interest, it can evolve into individual interest.[5] One subcategory of situational interest is value-based interest, which occurs when the student thinks the subject relates to their life and is important to know. For example, if an instructor teaches students about structural systems using a spaghetti bridge, they may show how that knowledge applies to real life, such as in the construction of real bridges, as illustrated in Figure 3. A visual representation of how these various types of interest interrelate is shown in Figure 4.

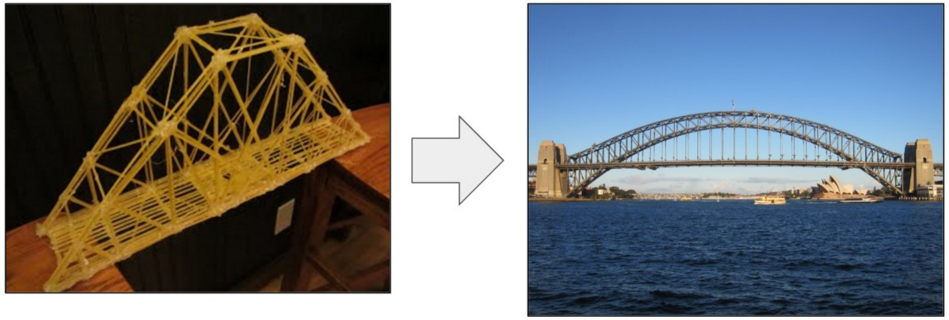


Figure 3. Successful activities demonstrate relevance to real world applications, such as how spaghetti bridge principles mirror real civil engineering principles.

Table 1. Comparison of motivation, engagement, and interest

	Implementation		Time Frame	
	Definition	Methods	Methods of Fostering	Measurement
Motivation	The desire or willingness of someone to do something.	Generated when a student is interested in a subject for a long period of time, and becomes invested enough to take action.	Long-term	Long-term
Engagement	How attentive and involved a student is in the moment.	Make a subject seem fun or cool.	Short-term	Short-term
Interest	How much a student cares about a subject.	Make a subject seem fun (short-term) and valuable (intermediate or long-term)	Short to intermediate-term	Short to Intermediate-term

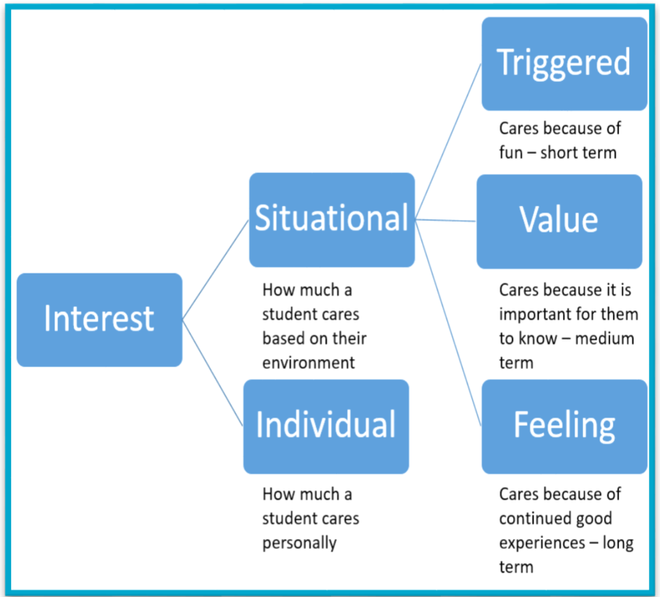


Figure 4. Subcategories of interest

Value-based interest can be formed by students during a few lessons, but for that to happen these lessons need to establish relevance to the student's life and increase their confidence in their ability to perform in that area.[5] Establishing relevance is important for students to understand the real-life relation and application of the learning material. When a student takes a humanities course, they are more likely to immediately see how the subject benefits their social and communication skills, while a math or science course might not offer the same apparent applicability.[7] In order for students to value STEM subjects, it is vital that they can relate the ideas to the real world and also have confidence in their own ability to learn and apply it.

Confidence and interest--especially value based interest--are often closely intertwined among students. While having a high self-confidence does not increase interest, having low confidence is related to having low interest. A study by Tytler was completed on students in Australia from Year 4 to Year 8 about self-confidence and interest in science. This study found 66% of students had high self confidence in Year 4, but only 49% of the same students have high self confidence when tested in Year 8. This trend was also present in the students' interest in science. 87% of these students were interested in science in Year 4, but only 67% were interested in science in Year 8. Tytler attributes the drop in interest to lower confidence levels with the material and argues for the need for activities to help increase student confidence.[8]

Ideally, an effective program will create value-based interest and confidence through tangible tasks that students can successfully complete. These tools have already been developed, and are in use today by many successful enrichment programs.

Table 2. Activity attributes that build interest

	Hands-On	Inquiry-based	Cooperative	Competitive
What it is	When the student is involved in the lesson	When the objective is to answer an open-ended question	Students working together in small groups of 3-4	Students competing against each other to accomplish a task "better" or faster
Benefits	•Increases short term interest •Increase confidence •Effective way to establish relevance	Helps the students learn to value the information and how it can be adapted to solve the problem	•Students are more involved •"Lower performing" students perform better than by themselves •Improves confidence	•Can increase interest in otherwise boring topics •Students are more invested in performing well
Limitations	Some safety limitations with lab activities	Must provide students with a great deal of structure	•Directions must be very clear •Students must be aware that they fail or succeed as a team	•All groups must have the same chance at winning •Unsuccessful participants can lose confidence

Pedagogical strategies used to build interest

There are many pedagogical strategies used to create relevance and increase confidence. Whether implemented in the classroom or as an extracurricular activity, making a program hands-on, inquiry based, cooperative, or competitive can better interest students in STEM fields, and help them understand the importance of STEM in their lives. These attributes are shown in Table 2.

Educators often employ hands-on activities to interest students. To do this, an instructor guides students through an activity that creates personal experiences with real materials to help students gain an understanding of a topic, as opposed to being lectured to about theory.[9] Students are often given a better understanding of their potential impact when they are engaged. In particular, "Hands-on learning has been implicated as one of the key factors that can improve a girl's confidence in the STEM areas."[10] In order for a student to develop interest in subject matter, a student must be confident in their ability to utilize it. One of the most popular hands-on STEM programs in the United States is the FIRST Robotics Competition (FRC). In this program teams of secondary school students design and build their own robots to compete against each other in various games. Because of the complex nature of a robotics team, FRC produces a culture of cooperation between students interested in business, community outreach, and engineering, allowing the program to demonstrate the relevance and practical side of STEM to a large variety of participants. The impact of FRC has been shown in a study completed by A.G. Welch, who found improved student attitudes towards math and science after participation in FRC.[11] Welch attributes much of this change to the real-world application of science, as well as interaction with FRC mentors.

Inquiry based activities allow students to follow the scientific method to solve open-ended problems, and conduct scientific investigations on their own. Students learn not only the information needed to solve the problem, but they gain a greater appreciation for the value of the process used to obtain scientific findings. Edelson, Douglass, and Roy found that, in order to assess the value of scientific findings, students should inquire for themselves, and produce scientific results.[12] An example of this inquiry-based approach to a STEM enrichment program is the CSIRO CREativity in Science and Technology (CREST) Program, where students pursue their own open-ended scientific investigation. Because “CREST is not a competition but a program which focuses on the individual and encourages success and the development of skills,”[13] a higher emphasis is placed on the scientific process as opposed to end results.

Another proven enrichment strategy to interest students is cooperative learning, which is where students work as a team to accomplish a task or to explore a question. When students are working in a collaborative group, they can each feel the group's appreciation for their contributions, making them feel valued.[14] For example, FRC demonstrates cooperative learning because of the teamwork required to build a robot. Each student contributes to one part of the robot, and they are all reliant on each other to get it done. Each student contributes to the overall success of the project, and as a result the team is able to accomplish lofty objectives in a short amount of time.

Competitive learning is carried out when students compete against one another to best achieve a common goal. While effective, this style must be employed carefully. When used appropriately these activities generate interest and reduce disruptive behavior among students, especially in regards to topics that would otherwise be considered boring.[15] Competitive learning is prominent in successful enrichment programs discussed previously, as well as Worldskills. This organization partners with industry specialists, and provides students an opportunity to train in various technical fields ranging from graphic design to welding. In WorldSkills Australia, students compete against each other in various technical fields at state, national, and international competitions, motivating them to master their trades to become the best in the world. Worldskills participant surveys in Australia revealed that involvement in the competitions and hands-on training were viewed by 77% of students as either significantly or critically beneficial to their careers.[16] Because of the competitive nature of this program, it has a lasting impact on students’ interest in a subject.

CSIRO is the leading scientific research organization of Australia and is attempting to integrate these best practices into their Science Bootcamp program.

CSIRO and the Science Bootcamp

Originally established by the Federal Government of Australia in 1916, CSIRO has been conducting research in various scientific fields to promote Australian defense, industry, and health (for an extended overview of CSIRO, see Supplemental Materials B). Over the past 30 years, CSIRO has expanded its focus to include the education of future scientists and technical workers through several programs, including the Science Bootcamps.

The Science Bootcamp program is targeted for Australian secondary school students ages 13 through 18. The bootcamp is a two day, non-residential program held on CSIRO campuses during school holiday breaks. There are two bootcamps held in each Australian capital city every year. In Science Bootcamps students are introduced to professional scientists, who explain their research and how it impacts the world at large. Students also complete a hands-on activity, where they "undertake various investigations and activities using scientific apparatus and technology."[17] CSIRO aims to inspire students to pursue STEM by showing them the real working environment of scientists as well as shedding light on the research and problem solving that scientists work on every day.

As a fairly new program—just two years old—the Science Bootcamp currently only employs four activities. These include a gel electrophoresis, a 3D printing activity, an audio amplifier, and a chem-magnetism activity, as described by Carly Siebentritt, the CSIRO National Bootcamp Coordinator. The gel electrophoresis activity allows a student to explore cellular biology, specifically techniques for DNA extraction. The 3D printing activity involves the design and physical testing of more effective 3D printed wind turbine. The other two activities, the phone speaker and ferrofluid, shown in Figure 5, were developed by previous WPI students working with CSIRO.[18] In the activities, students use 3D printing and electrical engineering to build a phone speaker, and magnetic fluids to clean up an oil spill. CSIRO is looking to expand and diversify their program to include more activities, so they can reach more students and foster their interest in STEM.

The literature shows that bolstering interest and building confidence are imperative and may motivate them to pursue STEM in the future. Employing the principles of hands-on work, relevance, inquiry, cooperation, and competition in the design of an activity may help make the activities more interesting to the students completing them. By incorporating these ideas into the design of new Science Bootcamp activities, the team intended to maximize the long-term im-

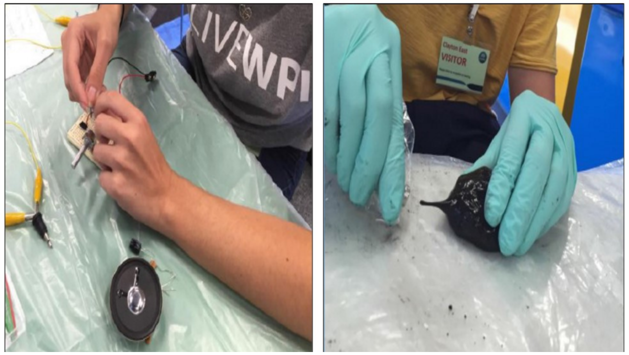


Figure 5. Past IQP students test running the phone speaker and ferromagnetic fluids activities.

pact of this program on students, and encourage them to consider further study and possibly careers in STEM fields.

Assessing previous CSIRO Science Bootcamps: What we learned

To better understand the success and impact of the Science Bootcamp program, CSIRO administers an exit survey to every student attendee. One of our objectives was to better understand how much students enjoyed each of the activities, and identify areas that can be improved upon.

While not all of the surveys distributed are identical, they all consist of fifteen open response, ranking, or multiple choice questions. The questions asked students how much they enjoyed the segments of the day (main activity, lab tours, research presentations, or other small activities), what their favorite and least favorite parts of the day were, what they enjoyed overall about the bootcamp, and how likely they would be to return to another bootcamp. Some of the surveys had students rank the same question on a different numerical scale than other surveys, while others presented the same question in a different way (i.e. a chart to choose topics from instead of an open response question). Overall, all of the surveys had commonly themed questions and asked for the same information, so they could be analyzed together.

The student surveys were distributed and collected at the end of the bootcamp. This section explains analysis and results for 346 student exit surveys from two years of Science Bootcamps.

Student survey research questions

In order to gauge the performance of the main activities and to aid in the improvement of the bootcamp experience, CSIRO intended to use the surveys to answer the following questions:

Questions focused on enjoyment:

- Did students find any of the activities particularly enjoyable or boring?
- Were any of the main activities more or less enjoyable to students than the rest?
- Did enjoyment of the main activities vary by location?
- Did enjoyment of the main activities vary by age?
- Did either gender enjoy any of the main activities more than the other?
- Did gender affect the likelihood of the student returning?

Questions focused on interest:

- Did students report they would like to return?
- Was the type of main activity correlated with students' reported likelihood of returning to another bootcamp?

Questions useful for future bootcamp design:

- Did the students enjoy the lab tours and presentations?
- What topics did students want to see in future bootcamps?

Student survey items

The surveys asked the age and gender of the student, as well as the location of the bootcamp. CSIRO gauged students' enjoyment of the activity by including the question in Figure 6(A). They generally rated the main activity of their camp on a scale from Poor (1) to Excellent (6), although some versions used a 1 to 4 numerical scale. The immediate rating of the activity is more likely to represent the short-term engagement than a student's intention to pursue it further.

Interest was measured by the student's reported likelihood to return which was on a scale from not likely at all (1) to very likely (7). Wanting to return to the bootcamp implies a desire to pursue these topics further. Examples of the likelihood-to-return question can be seen in Figure 6(B). This data was supplemented by 107 parent surveys. These surveys included a question on the likelihood of the parent to rebook, a measure of the student's interest as perceived by their parent.

To help see what future content might interest them, students were asked their favorite and least favorite part of the bootcamp (Figures 6C/D). CSIRO also asked for topics that they would like to see in future bootcamps (Figure 6E/F).

A)

Activity	Excellent	Very Good	Good	Fair	Disappointing	Poor
DIY gel electrophoresis activity across the two days	✓					

B) How likely are you to book into another Bootcamp (on a score of 1 – 7 where 7 is highly likely) 7

C) 5. Which was your favourite part of Bootcamp? Making Slime

D) 7. Which activity did you like least? Lab tours

E) What topic(s) would you like to see featured at Bootcamp? (Tick as many as you like)

Computer programming	✓	Geology		Robots	✓
Multimedia design		Physics		Greene energy	
Biology		Entomology		3D printing	✓
Chemistry		Electricity and circuitry	✓	Astronomy	✓

Other? ______

F) 13. What topic(s) would you like to see featured at Bootcamp? Experiments, Chemistry

Figure 6 (A-F). Questions and sample responses from student survey

Student Info		Bootcamp Info				Ranked Reasons								Rank Activities							
Age	Gender	Bootcamp	Location	Date	1. Why Attend?	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
12	M	Phone Speaker	Canberra	April 16	3, 4									Excellent	Very Goo	Very Goo	Very Goo	Good	Excellent	Excellent	Excellent
13	F	Phone Speaker	Canberra	April 16	2, 5									Excellent	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent	Very Good
12	M	Phone Speaker	Brisbane	April 16	1,4									Excellent	Very Goo	Excellent	Excellent	Very Goo	Excellent	Excellent	Excellent
13	F	Phone Speaker	Brisbane	April 16	1,2,5									Very Goo	Excellent	Excellent	Fair	Very Goo	Excellent	Excellent	Very Good
14	M	Phone Speaker	Brisbane	April 16	1,2,3,5									Very Goo	Very Goo	Very Goo	Excellent	Very Goo	Excellent	Excellent	Fair

(5) What was your favourite part of the bootcamp?		(6) What made this part most enjoyable?		(7) Which activity did you like the least?		(8) Why was this activity least enjoyable?		(9) What was the most important thing you learnt during the bootcamp?		(10) What did you like most about the bootcamp? (Please explain why)	
Keywords	Full Response	Keywords	Full Response	Keywords	Full Response	Keywords	Full Response	Keywords	Full Response	Keywords	Full Response
Everything	Everything	barleymax,	the activities, the barleymax	Presentation	Danny's presentation (just ba	Engaging	more engaging	Enzyme,	the Albatross	staff	presenters, this made
presentation:	The research presentations.	current research	Being able to learn about current research	n/a	I enjoyed all of the activities	n/a	n/a	electrophoresis	How gel Electrophoresis works	Everything	Everything... *illegible*
hands on activity		topic		n/a		n/a		friendship		hands on activities	hands on activities engaged my brain
lab tours	lab tours	interesting	it was really interesting! Exciting and inspired me. It was hands on			rnot relevant	not as relevant to what I want to do didn't start t day with a bang though they were very interesting, learnt many things	different jobs available	I learnt about what different people do, it made me question if there were any topics in science that I didn't enjoy	learning	I learnt many new things! I had so much fun
Quiz		thought	made me think	activity	audio amplphier	broke	it broke twice	technology	the technology was	quizes	quizes, lots of fun

Figure 7. Database of survey responses

Coding

To analyze the open-ended student responses, the team recorded responses verbatim and then coded them in the manner seen in Figure 7. We developed coding categories based on the actual bootcamp activities (for example "activity", "lab tour") and used these to code the responses. We each coded several surveys and refined our approach by comparing results.

Depending on the location and date of the bootcamp, similar closed-ended questions had been recorded on different scales. In order to merge the data, the team linearly scaled the data to make all of the responses on the same scale.

Findings from student surveys

Our analysis answered eight questions.

Were any of the main activities more or less enjoyable than the rest?

CSIRO was interested in determining if students enjoyed the four current activities, and also whether there were any significant differences between the student reported enjoyment of each activity. Overall the ratings for all of the activities were favorable, meaning the students enjoyed them (M=4.94). On the rating scale, 4 was "Good", 5 was "Very Good", and 6 was "Excellent." The 3D printing activities Hochberg adjusted means demonstrated that it was between "Good" and "Very Good" on average, while the phone speaker and magnetic slime activities were between "Very Good" and "Excellent" on average.

A one way ANOVA test ($p<0.05$) was conducted and revealed that there was a difference in the rating of these activities, $F(3,342)=3.06$, $p=0.03$. A post-hoc Hochberg test ($p<0.05$) showed that magnetic slime (M=5.28) was more enjoyable than gel electrophoresis (M=4.71), but not significantly more enjoyable than the 3D printing activity (M=4.86) or the phone speaker activity (M=5.12). Similarly, the 3D printing activity and the phone speaker activity are not significantly more enjoyable than the gel electrophoresis activity. The Hochberg results are shown in Table 3. The data groupings demonstrate if the means are different or not. If the means are in the same group it shows they are not statistically different. The results show that not all activities are equally enjoyable and that the less enjoyable activities (gel electrophoresis) could be improved.

Table 3. Hochberg distribution for student reported enjoyment of main activity

Activity	Mean Rating
Magnetic Slime	5.28
Phone Speaker	5.12
3D Printing	4.87
Gel Electrophoresis	4.71

Did enjoyment of the main activities vary by location?

CSIRO was also interested in how the different locations of the bootcamps affected the students' enjoyment. To determine this, our team used the survey question asking students to rate activities (Figure 6A). The location of each bootcamp was recorded on the surveys and put into our database. We split the dataset in SPSS by the main activity and ran four ANOVA tests of the locations and enjoyment levels ($p<0.05$). The phone speaker, $F(3,69)=0.72$, $p=0.54$, and magnetic slime, $F(1,55)=0.002$, $p=0.96$, enjoyment did not vary by location, but we found that the gel electrophoresis (Figure 8), $F(4,99)=53$, $p<0.001$, and 3D printing (Figure 9), $F(4,107)=17.58$, $p<0.001$, activities both differ. We then ran a post-hoc Hochberg test ($p<0.05$) which showed that the gel electrophoresis ($M=2.54$) and 3D printing ($M=3.42$) activities were significantly less enjoyable at Sydney than they were at other locations, while at Brisbane ($M=5.61$), the gel electrophoresis activity was as enjoyable as Melbourne ($M=5.39$) and Canberra ($M=5.42$), but more enjoyable than at Adelaide ($M=4.70$) and Sydney. The difference shown between the activities among the locations suggests that either cultural differences among the students in the different cities or the different instructors may play a role in the enjoyment of the activity.

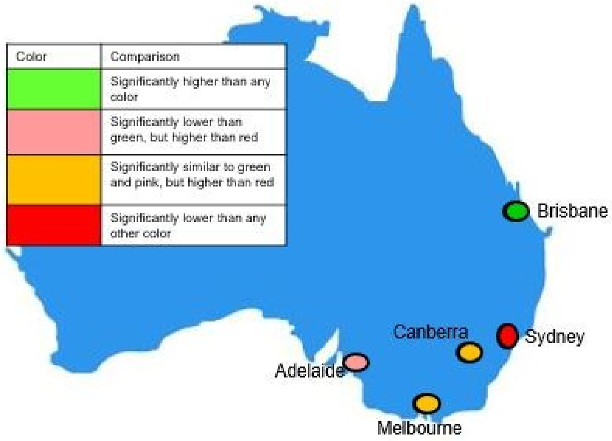


Figure 8. Statistical differences by location for the 3D printing activity

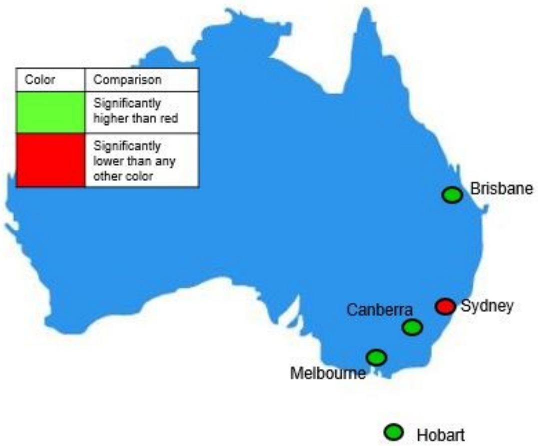


Figure 9. Statistical differences by location for the gel electrophoresis activity

Did enjoyment of the main activities vary by age?

To answer this question our group split the data in SPSS by activity, and then ran three ANOVA tests ($p<0.05$) using the student age as the independent variable and the rating for each activity as the dependent variable. The 3D printing activity had no data for age, so it was excluded from this analysis. While the tests for the gel electrophoresis, $F(4,29)=2.24$, $p=0.09$, and magnetic slime, $F(5,47)=0.88$, $p=0.50$, had no significant rating differences among different ages, the phone speaker, $F(4,68)=2.88$, $p=0.03$, found that students of different ages rated it differently. A post-hoc Hochberg test ($p<0.05$) showed that 15 year olds ($M=3.8$) enjoyed the phone speaker activity less than the 13 ($M=5.32$) and 14 ($M=5.28$) years olds, but as much as the 16 ($M=4.75$) and 12 ($M=5.00$) year olds as shown in Figure 10.

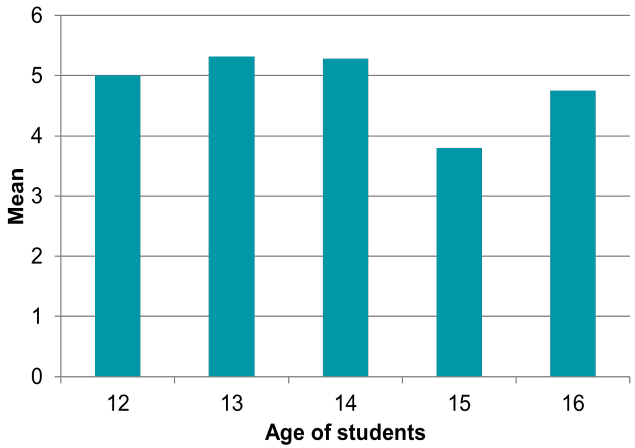


Figure 10. Hochberg distribution for age and enjoyment in the phone speaker activity

Does one gender enjoy any of the main activities more than the other?

In order to determine if there was a difference in enjoyment between the genders, the data was split by activity and four T-tests ($p<0.05$) were conducted. The 3D printing T-test found that there was most likely a difference with, $t(57)=-2.15$, $p=0.004$, while the rest of the activities found no difference with the phone speaker, $t(34)= -0.96$, $p=0.95$, the gel electrophoresis, $t(17)=-0.16$, $p=0.78$, and the magnetic slime, $t(8)=0.19$, $p=0.49$. The mean rating for females ($M=5.68$) for the 3D printing is higher than for the males ($M=4.89$). This demonstrates that female students generally enjoyed the 3D printing activity more than the male students (Figure 11). There was no significant difference between the genders with regard to their activity rating in the other main activities. The fact 3D printing was enjoyed more by females suggests bootcamp activities that are aimed towards girls should have similar aspects, such as a reliable take home item and strong real world connections to helping people.

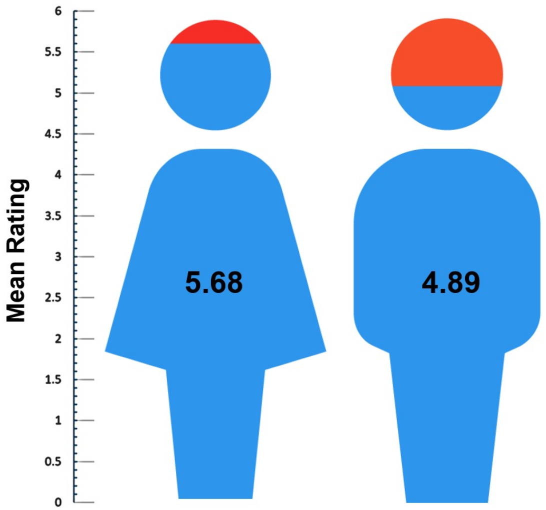


Figure 11. Mean rating of 3D printing activity by gender

Were male students more likely to report being interested in returning than females?

CSIRO was curious as to whether or not the male students were more interested in the subjects taught at the bootcamp than female students. To answer this question, we ran four T-tests ($p<0.05$), one for each activity. We found that there was no significant differences for any of the activities between gender and the student given likelihood of returning; the phone speaker, $t(34)=-0.80$, $p=0.14$, the gel electrophoresis, $t(17)=-1.16$, $p=0.22$, the 3D printing, $t(56)=-1.42$, $p=0.44$, and the magnetic slime, $t(8)=-0.24$, $p=0.37$.

Did the activity affect the student's likelihood of returning?

Overall, the students did state they were fairly likely to return to the bootcamp program, ($M=4.97$) out of 7. In our analysis, we used an ANOVA test ($p>0.05$) to determine if there were any significant differences in reported likelihood to return between students who attended bootcamps running different main activities. We found that there was no significant difference, $F(3,340)=1.23$, $p=0.30$, between activity and the student given likelihood of returning. This suggests that the interest generated in STEM by the bootcamp is independent of which of the main activities they did.

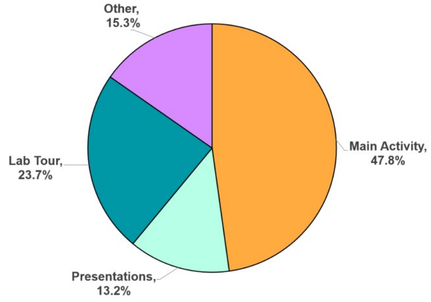


Figure 12. Students favorite segment of the day

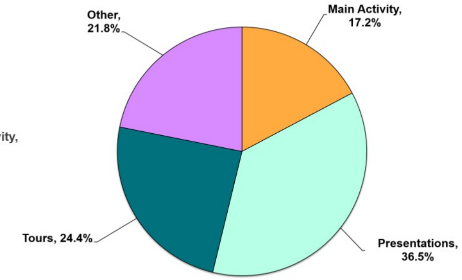


Figure 13. Students least favorite segment of the day

What did the students think of the lab tours and presentations?

CSIRO was also interested in what segment of the day the students most enjoyed, such as the main activity, lab tours, research presentations by CSIRO researchers, or other minor activities. To answer this, we used the open-ended survey question that explicitly asked the students about their favorite part of the bootcamp. We calculated the frequency with which each of the categories were mentioned. Students most often stated that they most enjoyed the main activity, followed by lab tours, as shown in Figure 12. Out of the 346 students who took the survey, 141 stated they enjoyed the main activity the most, followed by 70 stating they enjoyed the lab tours the most.

CSIRO also inquired about the student's least favorite part of the day. This was coded in a similar manner as responses to their favorite part of the day. The most common least favorite response was the research presentations with 87 responses, followed by lab tours with 58 (Figure 13).

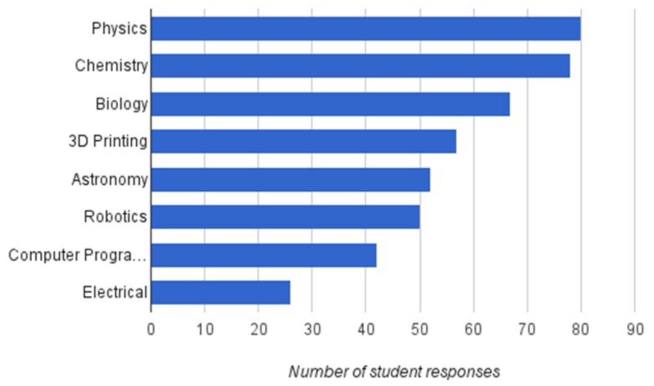


Figure 14. Top responses to what topic students would be interested in seeing for future bootcamps

What topics did students want to see in future bootcamps?

Figure 6E shows the chart from the survey students used to answer the question: "What topics would you like to see in the future?" The most common answer from students was physics (80), followed by chemistry (78), and biology (67). A full chart of the frequency of responses can be seen in Figure 14. This question was vital to the design of the team's future bootcamp activities because it allowed our team to choose a topic that prior bootcamp students were most interested in.

Parent survey and findings

CSIRO sent an email survey to parents once the bootcamp was completed to gather their opinion on the program. With the parent survey CSIRO wanted to answer the following questions in order to gain insight into how worthwhile the parents felt the bootcamp was to the students:

- Did any of the main activities have a high or lower likelihood of the parent rebooking?
- What did parents most often state as the most worthwhile aspect of the bootcamp?

Parent survey items

The parent surveys recorded the location of the child's bootcamp and information on how worthwhile the parent felt the bootcamp was. CSIRO asked the parents to rate how strongly they agree with the statement that they would book another bootcamp again from strongly disagree (1) to strongly agree (7). How strongly the parents agreed with the bootcamp being worthwhile was also asked with the same scale. The parents were then asked what about the bootcamp they saw as the most worthwhile in the form of an open response question. The parent surveys were coded in the same manner as described earlier in the student surveys section.

Did activity affect parent likelihood of rebooking?

Overall the data showed that parents were likely to rebook, averaging 4.4 out of 5 without looking at a specific activity. In order to determine if an activity had an effect on the likelihood of the parent rebooking, we ran an ANOVA test ($p<0.05$) on the given likelihood of the parent rebooking split by the main activity that their student did. There was no data recorded for the magnetic slime and slick activity so it was excluded from this analysis. We found that there was no difference, $F(2,83)=1.01$, $p=0.37$, in likelihood to rebook between the phone speaker, 3D printing, or gel electrophoresis activities.

Most worthwhile aspect of the program to the parents

In the parent survey CSIRO wanted to know what they saw as the most worthwhile aspect of the bootcamp. This coding used the same process as presented previously. The complete list of coding categories for this question and previous ones appear in supplemental material C. As seen in Figure 15, most of the parents that responded felt that the exposure to science was the most worthwhile part of the bootcamp, followed by their children being able to socialize with other students that have similar interests.

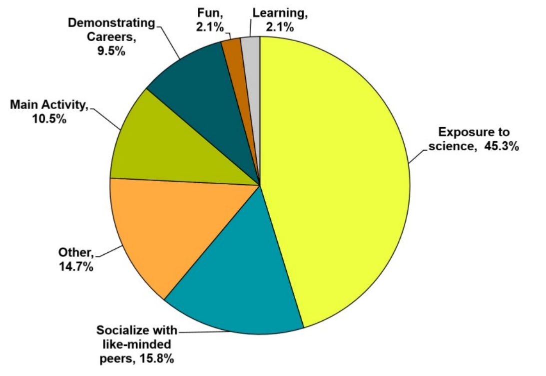


Figure 15. Most worthwhile aspects to parents

Takeaways for the development of activities

Our analysis also validated our third objective, to make new hands-on bootcamp activities, as we found that they were by far the favorite part of the bootcamp program. Overall, the Science Bootcamps are performing well and are generally well received by students. Lab tours and researcher presentations were enjoyed by students--one of CSIRO's most important goals. It revealed the most desired activity topics, which we kept in mind when designing new activities. It also brought to our attention that the hands-on nature of the activities, having a consistently functional take home item, and relating the activity to helping others helps to engage females, as shown specifically in the enjoyment of the 3D printing activity. The information gathered was helpful in guiding the team's planning of new bootcamp activities. For a full description of the outcomes of the analyses, see Supplemental Material D.

Design and development of bootcamp activities

The third objective of this project was to design and develop two new Science Bootcamp activities to pique Australian students' interest in science and technology, while emphasizing the scientific research of CSIRO. We chose topics for the activities highlighted by students in the post-bootcamp surveys, namely astronomy, chemistry, and biology, and brainstormed possible activities. We analyzed these using a decision matrix, allowing us to rank each activity by seven criteria, as shown in Figure 16. The full matrix is available in Supplemental Materials E.

The team took the six highest ranked activities and discussed their potential with CSIRO educational experts. The pros and cons of each activity are shown in Table 4. This discussion narrowed down the activities to the toothpaste and do-it-yourself electrocardiogram activities. We also introduced a spacecraft design activity, as the experts wanted to publicize CSIRO's astronomy accomplishments. The team initially developed the make-your-own toothpaste activity, but due to unenthusiastic tester response, decided to leave it for a future group to finish developing.

Table 4. Reasons for and against each activity concept.

Activity Selection		
Activity	**For**	**Against**
Chromatography	•Chemistry based	•Potentially boring •Too much waiting •Not enough activity material
Make-your-own Toothpaste	•Design based •Relatable to Chemistry	•Potentially boring
Telescope	•Astronomy related	•Too similar to younger student's activities
Homopolar Motor	•Physics related	•Wrong time frame •Too difficult
Magnetogravity slingshot	•Physics related •Astronomy related	•Impractical •Too difficult
Water bottle rocket	•Physics Related •Astronomy related	•Too similar to younger students activities
Do-it-Yourself Electrocardiogram	•Biology Related •Can easily be related to relevance/helping people	•Electronics activity already in use

Activity	Cost	Doesn't Need Equipment	Right Difficulty/timeframe	Takewaway	Relateable to CSIRO	Desired Topic (Physics, Chemistry, Biology, Astronomy, Robotics)	Safety	Total
Chromatography	1	1	0	1	1	1	1	5
Testing toothpaste	1	1	1	1	1	1	1	6
Solar Cookers	1	1	0	1	1	0	1	4
Lava Lamps	1	1	0	1	0	1	1	4
DIY EKG	1	1	1	1	1	1	1	6
Rollarcoaster	1	1	1	0	1	1	1	5
All terrain wheelchair R&D	1	0	1	1	1	0	1	5

Figure 16. Portion of decision matrix used to narrow possible activities

Design process

Once the two Science Bootcamp activities were selected, the team iteratively tested and developed them. A visual representation of our methods can be seen in Figure 17. From the start, we built in teamwork and hands-on features, using pedagogical strategies discussed previously. We conducted pretesting ourselves and did additional testing with other students, refining the activity templates and instructions further. Finally, upon speaking with CSIRO educational experts, the team redesigned some activity aspects.

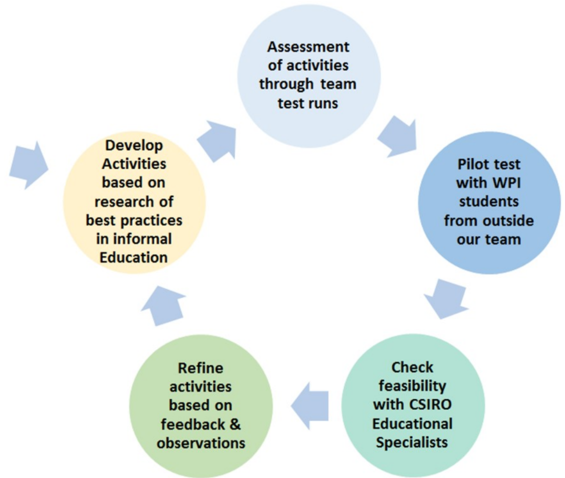


Figure 17. Iterative process for activity development

Preliminary design: Astronomy activity

The astronomy activity incorporates interest-generating aspects of hands-on activities, such as elements of inquiry-based, competitive, and cooperative learning. In this activity, students design and build their own spacecraft, then test it to determine if it would survive the tribulations of space travel. This can easily be related to CSIRO's extensive research in deep space observations and communication assistance during the lunar landings.

The team began by considering different tests the completed spacecraft could undergo, which would provide design criteria. During each of the tests the spacecraft contains an egg, representing the astronaut, and each test represents different challenges in space travel (Table 5).

The team also determined appropriate materials for the construction of the spacecraft. We chose inexpensive household materials such as cardboard, as well as more specialized materials such as gasket tape. A complete list of the spacecraft build materials can be found in Supplemental Materials F.

Table 5. Summary of proposed spacecraft student tests

Astronomy Activity Possible Tests			
Test	**Relevance**	**Procedure**	**Materials**
Aerodynamics	Spacecraft must be aerodynamic to escape the atmosphere efficiently.	Place the spacecraft on a cart in front of a fan. The less it moves, the more aerodynamic it is.	Fan, Cart
Impact	Spacecraft must be durable in case of a hard landing.	Drop the spacecraft from a high place. If the egg breaks, it is not impact resistant.	Stepladder
Heat	Spacecraft must be resistant to heat because of the heat caused during reentry into earth's atmosphere.	Aim a heat gun at the spacecraft. If a thermal sensor on the egg changes color, the heat shielding fails.	Heat gun, thermal sensors
Air-tight	Spacecraft must be airtight to preserve oxygen in the vacuum of space.	Submerge the spacecraft in water. If a paper towel wrapped around the egg is wet after submersion, the test is failed	Container filled with water
Dust	Spacecraft must keep out dust because of the abundant dust on other planets.	Weigh the spacecraft. Place the spacecraft in the sand-filled container and shake. Remove the craft and weigh it. If the spacecraft weighs more, the test is failed.	Large plastic container, sand, scale

Preliminary Design: ECG activity

The electrocardiogram (ECG) activity provided a topic that many students had expressed interest in (biology), as well as insight into a technology that has relevance in many students' lives—as most have been in a hospital either for themselves or a relative. The students build an electrocardiogram—a device that monitors electrical signals from the heart—and use it to explore biosignals and cardiovascular health.

The team began by designing a basic and inexpensive electrocardiogram amplifier circuit to amplify the difference in electrical voltage across an individual's forearms. The design utilizes a headphone jack connection plugged into a computer and analyzes the signal using an audio recording software. The completed initial design can be found in Supplemental Materials G. After some troubleshooting and redesign, the team successfully built the electrocardiogram. An image of testing is shown in Figure 18.

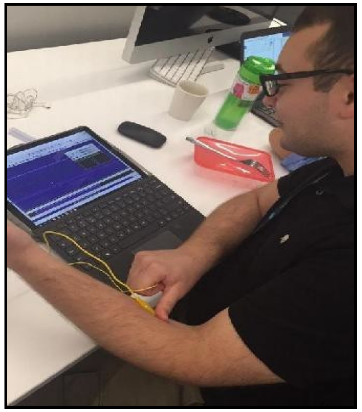


Figure 18. Testing of first ECG prototype

We created student instructions to construct the ECG, making breadboard images—pictures of what the actual circuit should look like (Figure 19). These images were then compiled into a document with assembly instructions. Then, we developed an activity sheet that outlined ways to explore how the body's actions affected the displayed heartbeat.

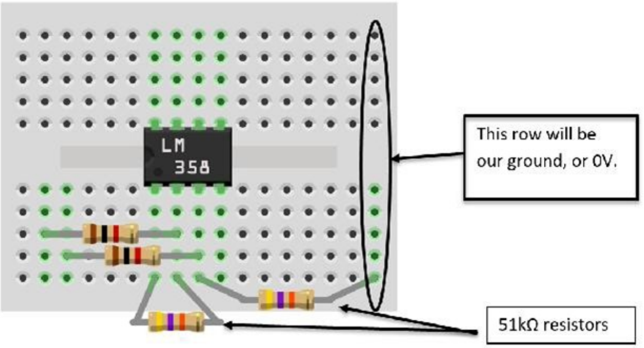


Figure 19. Sample breadboard images.

Preliminary self-testing

Our own pre-test of the ECG and spacecraft activities was completed to ensure the activities could be done in the allotted time with the provided materials. We used a general guideline of two-and-a-half hours to pre-test the building of the prototype spacecraft. Each member sketched a design, built the physical model, and tested their models (Figure 20). The results from the self-test can be seen in Table 6.

Given the successful pre-test, we then created a student worksheet outlining the various tests that the spacecraft would undergo and providing space for the student to sketch a preliminary design. The team decided that the students would be allowed to purchase the materials they desire from a shop. They would receive a fictional budget of $1,000, and the cost of the materials was scaled so that this was the equivalent of 8 AUD.

Self-testing of the ECG activity was completed during the preliminary design period. Portions of the activity were completed individually and team members reviewed them as progress was made. The team focused on the clarity of the instructions, so students could complete the construction in a reasonable amount of time. Results are shown in Table 7.

Figure 20. Spacecraft prototypes from self-test

Table 6. Results and revisions from astronomy activity self-test

Astronomy Self-Testing -- Results; N=4				
Time	Target: 4 hours: 2 building, 2 testing		Actual: 4 hours, 2 building, 2 testing	
Testing Success rate	*Drop-test*	*Aerodynamics*	*Heat Resistance*	*Air Tight*
	3/4	4/4	4/4	1/4
Price	Target: $15.00 per student		Actual: Average $8.00 per student	
Confusion	•The amount of materials necessary for building a spacecraft was unknown (i.e. how much should be allowed in later testing).			
Observations	•Some participants took too long to build their spacecraft.			
Revisions	•The team measured materials used for the spacecraft to establish a ballpark estimate of materials students would use. A budget system was established and students are now given a "budget" and have access to a "shop" for materials. •The order of the tests was changed to make water test last to preserve spacecraft as long as possible.			

Table 7. ECG self-testing results

ECG Self-Testing -- Results; N=2		
Time	Target: 4 hours: 2 building, 2 testing	Several hours (untimed)
Price	Target: $15.00 per student	Actual: $14.90
Success Rate	2 functional ECGs were created	
Confusion	•Schematic of circuit was too complicated for the age group without a lot of guidance. •Issues occurred when trying to make it work on different computers.	
Observations	• ECG could be built on the breadboard used for phone speaker, but needed to be planned carefully. •ECG could also be used as EMG (electromyogram, tracks muscular electrical signals) to diversify inquiry questions. •A free audio editing software worked well with the signal. •Two batteries may be too high a voltage to be safe.	
Revisions	•Step-by-step instructions were created with visuals to walk the student through the construction. •A single battery design was implemented. •Diodes were added as a safety feature between outputs.	

This self-testing guided the development of the instructional material and improved how the device would be built. In addition, the observations helped the team to improve the flow of the post-construction activities.

Peer testing

In order to gain a better understanding of how the activities would fare in a real Science Bootcamp environment, the activities were tested with our peers from Worcester Polytechnic Institute. The team utilized an observation sheet (Figure 21) to organize notes as the activity progressed. Images of peer testing appear in Supplemental Materials H.

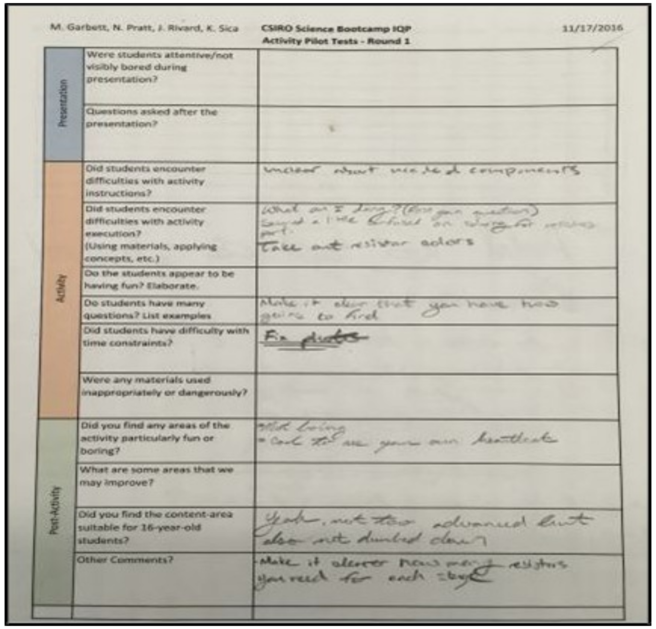
Spacecraft

The results from peer testing are summarized in Table 8. The completed spacecraft are shown in Figure 22. The peer testing suggested that the activities were enjoyable and could be completed on time with the appropriate materials, but it also highlighted necessary improvements such as clarifying instructions.

ECG

Two WPI peers, and one year 10 Australian student, tested this activity. Each student built a working ECG within the time constraints. The results from the peer testing are in Table 9 and a student completing the project with his ECG output can be seen in Figure 23.

While the team had prepared worksheets for post construction activities, they were not tested because we lacked the materials. However, the students enjoyed building the device and the year 10 student managed to operate his circuit as an EMG, detecting the muscle contractions in his forearm. The team used this feedback to make the instructions clearer.


M. Garbett, N. Pratt, J. Rivard, K. Sica — CSIRO Science Bootcamp IQP — Activity Pilot Tests - Round 1 — 11/17/2016

Presentation	Were students attentive/not visibly bored during presentation?	
	Questions asked after the presentation?	
Activity	Did students encounter difficulties with activity instructions?	[illegible]
	Did students encounter difficulties with activity execution? (Using materials, applying concepts, etc.)	[illegible] Take out resistor colors
	Do the students appear to be having fun? Elaborate.	
	Do students have many questions? List examples	[illegible]
	Did students have difficulty with time constraints?	[illegible]
	Were any materials used inappropriately or dangerously?	
Post-Activity	Did you find any areas of the activity particularly fun or boring?	[illegible]
	What are some areas that we may improve?	
	Did you find the content-area suitable for 16-year-old students?	Yeah, not too advanced but also not dumbed down
	Other Comments?	Make it clearer how many resistors you need for each stage

Figure 21. Observation sheet used for peer testing

Table 8. Results and revisions from peer testing the astronomy activity

Astronomy Peer Testing -- Results; N=3				
Time	Target: 3 hours: 2 building, 1 testing		Actual: 3 hours: 2 building, 1 testing (one student finished building early by 1 hour)	
Testing Success rate	*Drop-test*	*Aerodynamics*	*Heat Resistance*	*Air Tight*
	2/3	3/3	3/3	1/3
Confusion	•Questions were asked early about design parameters, materials, and testing. •The instructional materials were not always clear regarding procedures in these areas. •Tests were not fully defined in the handouts.			
Observations	•Activities were completed within the time limits. •One student failed two of the tests (but rushed through the build stage). •Two other students failed one test each.			
Revisions	•More detail was added to the written instructions, including information on the design parameters, materials, and pre-testing. •The presentation was edited to better convey the format of the activity.			

Figure 22. Prototypes spacecraft from WPI peers

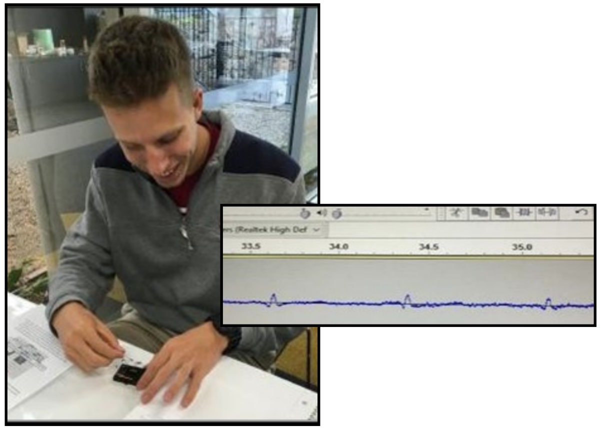


Figure 23. WPI peer completing the ECG activity

Specialist review of activities

After revisions were made based on the self and peer testing, completed materials were presented to an educational specialist for review of feasibility and clarity.

Astronomy

When the instructions were reviewed, it was determined that they were too structured for secondary school students. The educational specialist suggested the testing be revised, so the students design the tests themselves in a more inquiry-based style. Long wait times were a concern due to the large class size and were reduced by using multiple testing stations.

ECG

The educational specialist completed the ECG with the step-by-step instructions to identify any issues. Observations, results, and revisions can be seen in Table 10.

Table 9. Results and revisions made from ECG peer testing

ECG Peer Testing -- Results; N=3		
Time	Target: 3 hours: 2 building, 1 testing	Actual: 2 hours, build only
Success Rate	3/3 built a functional ECG	
Confusion	•There were mistakes in the circuit diagram. •Circuits did not work immediately. •One student could not get her biosignal to show up.	
Observations	•Students enjoyed creating the ECG. •Worked consistently when troubleshooting complete. •Signal easily seen without extra filtering in the software.	
Revisions	•Troubleshooting guide was created for students to walk through issues on their own. •Pictures in instructions were edited to fix color errors, and to match the questions more.	

Table 10. Observations and revisions to ECG activity after the Educational Specialist completed it.

ECG Educational Specialist Review -- Results		
Time	Target: 2 hours	Actual: 45 minutes
Success rate	1/1 Participant built a working ECG	
Confusion	•Pointed out issues with there being too many instructions per step. •Discovered holes in the instructions. •Missing Feedback wire instructions. •Some pictures were still incorrect. •Signal was not detected on educational specialist, but it was on team member.	
Observations	•Instructor troubleshooting guide needed. •Missed some instructions due to paragraph structure. •Math took longer than expected. •Instructor built it correctly on the first try.	
Revisions	•Student instructional material updated. •An instructors guide was created to help students quickly with common problems. •Changed resistor values so that anyone's heartbeat would appear.	

Final outcomes

The revised astronomy activity focuses on CSIRO's role in astronomy and space exploration. The four-hour activity begins with a short presentation, followed by a design and build phase, then a testing phase. Students are introduced to requirements for a real spacecraft, and must budget resources to build a spacecraft that meets these criteria. The students create their own tests with given materials and discuss if their tests were representative of what is required of actual spacecraft. Supplemental activities were included for the students to perform during downtime between testing phases.

During the ECG activity, the basic concepts behind the nervous and cardiovascular systems are explained, including how signals are produced and how medical devices can detect these signals, to learn more about health and the body. CSIRO has done research on these biosignals, as seen in the development of techniques for interpreting EEG and ECG signals to replace more invasive procedures. The students build and then test an ECG with questions to familiarize them with the device, later conducting their own experiments

The activities required specific deliverables, described in Table 11, which include an activity template (Figure 24), presentations (Figure 25 and 26), student handouts, (Figure 27 and 28) and information for CSIRO to reformat into take home notes. The full deliverables can be found in Supplemental Materials sections I through K for the spacecraft activity and L through N for the ECG. These deliverables will enable the activities to be run at the bootcamps with minimal adjustments from the CSIRO educational experts. Like all educational programs, they will likely require revision after the first full-scale implementation.

Day 1

- The grand scale of the Universe, and what CSIRO is doing to learn more about many of its components
- CSIRO's global role in Astronomy
  - Their renowned radio telescopes, and what a radio telescope is
  - The research being done with receivers and signal amplifying systems
  - Applications of these technologies
  - Spacecraft tracking systems
  - Study of pulsars to learn about galaxy formation
  - Development space-related of technology used in daily life
  - Technology for communicating with spacecraft on missions and in orbit
- Stages of travelling outside of Earth's orbit and beyond
  - Launch
    - **TEST (aerodynamics)**, aerodynamics necessary to leave the atmosphere because otherwise it would require too much fuel
    - *Materials:* cart, fan, stopwatch, and ruler.
    - *Possible test:* "top" of spacecraft parallel to the table and the spacecraft laying on its side on the cart, place the cart 20 cm away from the fan with the "top" pointing toward it, let the fan run for 45 seconds and measure the distance it moved
    - *Possible positive outcome:* spacecraft does not move at all, overall the less it moves the better because the air is not exerting enough force on it
  - Space travel
    - **TEST (air tightness)** oxygen is vital to life- spacecraft must be airtight, if water can get in air can get out, Air bubbles are gas escaping
    - *Materials:* stopwatch, bucket ½ filled with water, paper towels
    - *Possible test:* wrap the astronaut in a dry paper towel, then reseal the spacecraft and fully submerge in water for 30 seconds
    - *Possible positive outcome:* paper towel around egg comes out dry and no air bubbles come out of the craft while under water
    - **TEST (dust resistance)** try to keep dust out of space craft, Space craft must keep outside material from entering air vents/electrical components/living area because it can harm the devices and be harmful if breathed in
    - *Materials:* box filled with sand, scale, stopwatch
    - *Possible Test:* take the spacecraft's mass before placing in the box, record the value, place spacecraft in box, snap on the lid, and shake for 30 seconds, remove spacecraft, only knocking off sand directly on top/outside of the spacecraft, take its mass again and record the mass, determine the difference to see how much sand it took on.
    - *Possible positive outcome:* the less the mass of the spacecraft increases the better.
  - Returning to Earth

Figure 24. Outline of Astronomy Science Bootcamp from the activity template

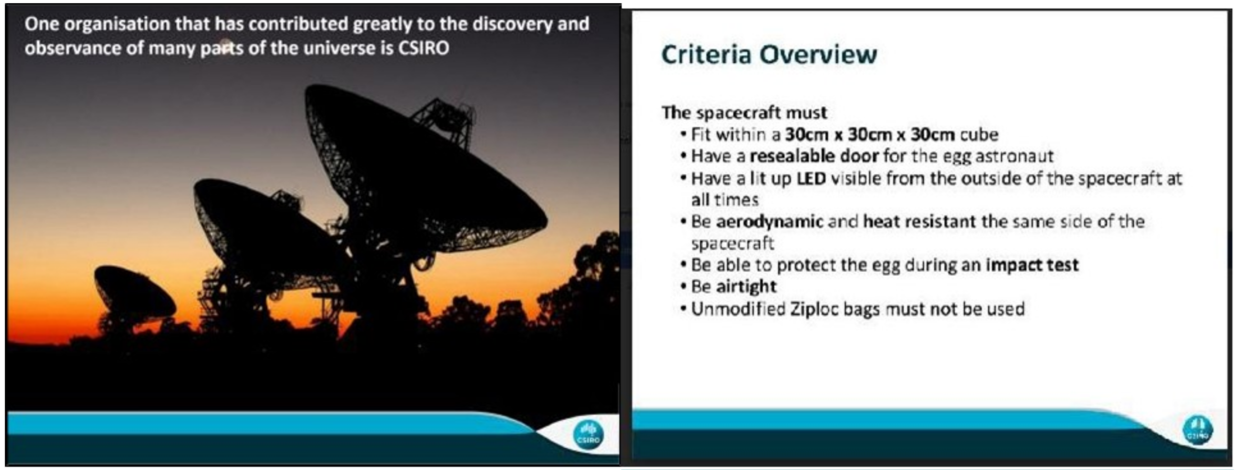


Figure 25. Astronomy presentation slides about CSIRO's radio telescopes and spacecraft criteria

Table 11. Deliverables

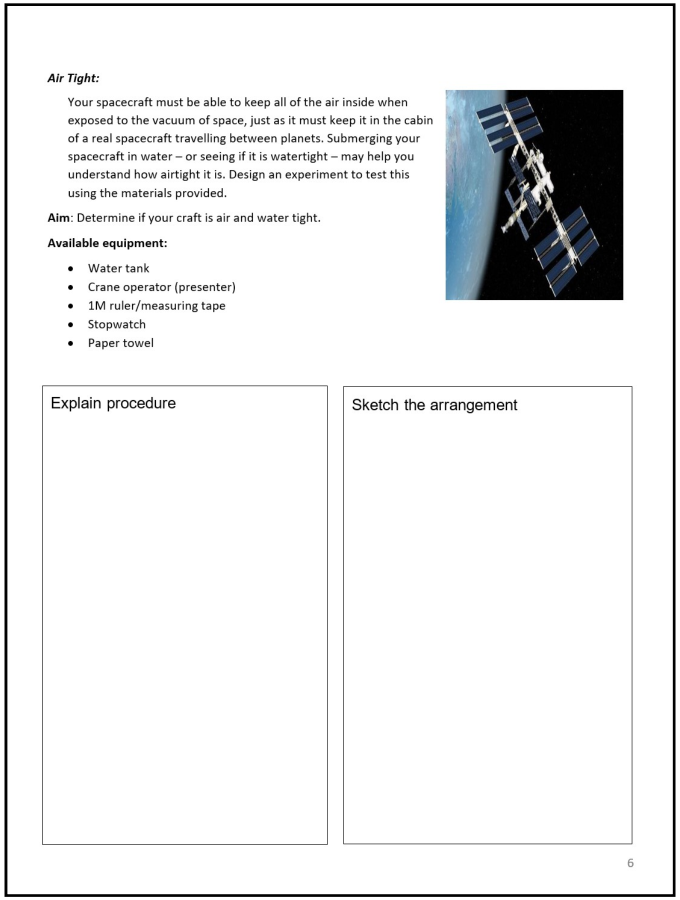
Deliverable	What is in it	Who it is for	Focus For Astronomy Activity	Focus for ECG Activity
Template	•Activity Overview •Activity Timeline •Risk Assessment •Instructor Notes • Material List with suppliers and prices	Instructor	•Testing logistics •Supplemental activities for downtime	• Circuit construction procedures •Relevant concepts to student
Presentations	•Background on topic •Connections to CSIRO Research •Introduction to Activity	Instructor to deliver to student	•Space exploration •Radio Telescopes •Materials used in spacecraft •Spacecraft Conditions	•Nervous system and biosignals •Medical equipment •Electrical components on the ECG
Student Handouts	•Instructions for activity •Space to design tests/experiment	Student	•Material list for the spacecraft •Budget sheet •What each test represents for a spacecraft	•Instructions for building ECG •Troubleshooting guide •Experiment sheet
Take Home Notes	•Additional information on topic •Additional activities •CSIRO Stories (more connections)	Student	•How space is explored from Earth •More tests for spacecraft •DIY telescope activity	•Research involving CSIRO and Biosignals •Additional ECG investigation •Heartbeat activity

Figure 26. ECG Slide about CSIRO's home care development

Recommendations and Conclusions

To aid in future development of the CSIRO Science bootcamp program, we suggest the following:

- **Assessment:** Standardize surveys to simplify data analysis. Additionally, modify survey questions to focus on changes in student interest, rather than enjoyment (See Supplemental Materials O).
- **Long-term impact:** Provide students with resources on how to get involved with longer-term STEM education programs or organizations like robotics teams, math olympiads, or other after-school programs to encourage pursuit of future studies and careers.
- **Activity Development:** Test the activities with other WPI students, or Australian secondary school students earlier in the timeline of development to allow for more iterations based on participant feedback.



Air Tight:

Your spacecraft must be able to keep all of the air inside when exposed to the vacuum of space, just as it must keep it in the cabin of a real spacecraft travelling between planets. Submerging your spacecraft in water – or seeing if it is watertight – may help you understand how airtight it is. Design an experiment to test this using the materials provided.

Aim: Determine if your craft is air and water tight.

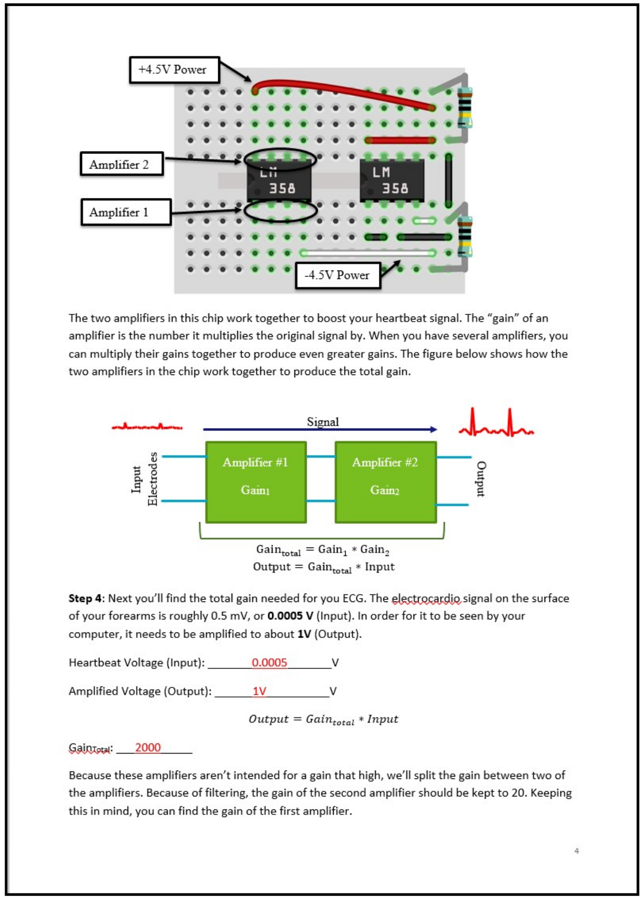
Available equipment:

- Water tank
- Crane operator (presenter)
- 1M ruler/measuring tape
- Stopwatch
- Paper towel

Explain procedure	Sketch the arrangement

6

Figure 27. Example of Astronomy Student worksheet



The two amplifiers in this chip work together to boost your heartbeat signal. The "gain" of an amplifier is the number it multiplies the original signal by. When you have several amplifiers, you can multiply their gains together to produce even greater gains. The figure below shows how the two amplifiers in the chip work together to produce the total gain.

$$\text{Gain}_{total} = \text{Gain}_1 * \text{Gain}_2$$
$$\text{Output} = \text{Gain}_{total} * \text{Input}$$

Step 4: Next you'll find the total gain needed for you ECG. The electrocardio signal on the surface of your forearms is roughly 0.5 mV, or **0.0005 V** (Input). In order for it to be seen by your computer, it needs to be amplified to about **1V** (Output).

Heartbeat Voltage (Input): ____0.0005____V

Amplified Voltage (Output): ____1V____V

$$Output = Gain_{total} * Input$$

Gain_{Total}: ____2000____

Because these amplifiers aren't intended for a gain that high, we'll split the gain between two of the amplifiers. Because of filtering, the gain of the second amplifier should be kept to 20. Keeping this in mind, you can find the gain of the first amplifier.

4

Figure 28. Example of ECG Student Instructions

In the process of researching science instruction methods, analyzing previous bootcamp survey data, and developing new activities, we learned to effectively meet deadlines as a group. Our activities will be implemented and further refined by CSIRO educational experts during their upcoming Science Bootcamp programs. We hope that the interest students develop will encourage them to continue their education in STEM fields.

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Supplemental Materials for this project (raw data, research instruments, and additional project references, background, and outcomes) can be found at http://www.wpi.edu/E-project-db/E-project-search/search, using key words from the project title.