No Roadblocks in Low Earth Orbit: The Motivational Role of the Amateur Radio on the International Space Station (ARISS) School Program in STEM Education

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Abstract

This study presents an investigation of the interaction with a role model and school students' interest in pursuing Science, Technology, Engineering, and Mathematics (STEM) subjects. The interaction is in the form of a live question and answer contact with an astronaut aboard the International Space Station (ISS). Through the integration of the Amateur Radio on the International Space Station (ARISS) School Program into the school curriculum as an external intervention, opportunities are provided for school students from anywhere in the world to ask their own prepared questions of the astronauts using two-way Amateur Radio. The purpose of this research is to determine the extent to which the ARISS Program is meeting its primary goal of enhancing school students' interest in STEM subjects and to analyse any changes in student interest towards STEM subjects and STEM based careers attributed to the ARISS program. Data were collected through a mixed methods research model using pre- and post- event online questionnaires, from 236 students and 31 teachers, representing 4 schools, and 29 ARISS Volunteers. Case Study students and teachers were chosen

from Canada, Germany, and the United States. Very high ARISS excitement levels were exhibited by the students and teachers from all case study schools. A t-test was used to determine the significance of student pre- and post-event interest and excitement levels, and while science was the only subject with a significant difference, there was a noticeable positive trend in the change in student STEM interest within all subject areas. There were twice as many students reporting an increase in STEM interest than not at the conclusion of the ARISS event. Participant teachers unanimously reported that astronauts, male and female, are a significant positive role model for school students, and that the ARISS program was of value to their students. More primary aged students exhibited a positive STEM interest change than secondary aged students. A positive change in STEM subject interest within secondary school age students exists pointing to the ability of the ARISS program to motivate older students. This research confirms that the ARISS program has a significant and positive impact on students where an integrative partnership with the school curriculum is achieved. This research has contributed to the existing literature surrounding the impact of inspirational expert role models on the motivation levels of students to pursue STEM based studies and careers.

Keywords: STEM, ISS, ARISS, Situated Cognition, Role Models

Sin obstáculos en la órbita terrestre baja: el papel motivacional del programa escolar de radioaficionados en la Estación Espacial Internacional (ARISS) en la educación STEM

Resumen

Este estudio presenta una investigación de la interacción con un modelo a seguir y el interés de los estudiantes en cursar materias de Ciencia, Tecnología, Ingeniería y Matemáticas (STEM). La interacción se realiza en forma de contacto en vivo de preguntas y respuestas con un astronauta a bordo de la Estación Espacial Internacional (ISS). A través de la integración del Programa Escolar de Radioaficionados en la Estación Espacial Internacional (ARISS) en el plan de estudios escolar como una intervención externa, se brindan oportunidades para que los estudiantes de cualquier parte del mundo hagan sus propias preguntas preparadas a los astronautas

utilizando sistemas bidireccionales. Radioaficionados. El propósito de esta investigación es determinar en qué medida el Programa ARISS está cumpliendo su objetivo principal de mejorar el interés de los estudiantes en las materias STEM y analizar cualquier cambio en el interés de los estudiantes hacia las materias STEM y las carreras basadas en STEM atribuidas al programa ARISS. Los datos se recopilaron a través de un modelo de investigación de métodos mixtos utilizando cuestionarios en línea previos y posteriores al evento, de 236 estudiantes y 31 profesores, que representan 4 escuelas, y 29 voluntarios de ARISS. Los estudiantes y profesores del estudio de caso fueron elegidos de Canadá, Alemania y Estados Unidos. Los estudiantes y profesores de todas las escuelas estudiadas mostraron niveles muy altos de entusiasmo por ARISS. Se utilizó una prueba t para determinar la importancia del interés y los niveles de entusiasmo de los estudiantes antes y después del evento, y si bien ciencias fue la única materia con una diferencia significativa, hubo una tendencia positiva notable en el cambio en el interés de los estudiantes en STEM dentro de todas las áreas temáticas. Al finalizar el evento ARISS, hubo el doble de estudiantes que informaron un aumento en el interés por STEM que los que no lo hicieron. Los maestros participantes informaron unánimemente que los astronautas, hombres y mujeres, son un importante modelo positivo para los estudiantes de la escuela, y que el programa ARISS fue valioso para sus estudiantes. Más estudiantes de primaria exhibieron un cambio positivo en el interés por STEM que los estudiantes de secundaria. Existe un cambio positivo en el interés por las materias STEM entre los estudiantes en edad de escuela secundaria, lo que apunta a la capacidad del programa ARISS para motivar a los estudiantes mayores. Esta investigación confirma que el programa ARISS tiene un impacto significativo y positivo en los estudiantes cuando se logra una asociación integradora con el plan de estudios escolar. Esta investigación ha contribuido a la literatura existente sobre el impacto de los modelos inspiradores de expertos en los niveles de motivación de los estudiantes para realizar estudios y carreras basados en STEM.

Palabras clave: STEM, ISS, ARISS, Cognición situada, Modelos a seguir

近地轨道无障碍：“国际空间站之业余无线电通信”(ARISS)学校计划在STEM教育中的激励作用

摘要

本研究调查了“与榜样的互动”以及学生对科学、技术、工程和数学(STEM)科目的兴趣。互动形式则为：与国际空间站(ISS)上的一名宇航员进行实时问答联系。通过将“国际空间站之业余无线电通信”(ARISS)这一学校计划作为外部干预纳入学校课程，为来自世界各地的学生提供了机会，即使用双向互动的业余无线电通信向宇航员提出自己准备好的问题。本研究旨在确定ARISS计划在多大程度上实现了其主要目标——提高学生对STEM科目的兴趣；并分析因ARISS计划而导致学生对“STEM科目和基于STEM的职业”的兴趣变化。通过一项混合方法研究模型进行数据收集，研究模型使用了活动前后的网络问卷调查，问卷填写人包括来自4所学校的236名学生和31名教师，以及29名ARISS志愿者。案例研究的学生和教师来自加拿大、德国和美国。所有案例研究学校的学生和教师都对ARISS计划表现出了很高的兴奋程度。使用t检验确定“学生活动前后的兴趣和兴奋水平”的显著性。检验结果发现，虽然科学是唯一具有显著差异的学科，但学生对所有学科领域的STEM兴趣变化均呈现出明显的积极趋势。ARISS活动结束时，“对STEM兴趣增加”的学生人数是“未增加STEM兴趣”的学生人数的两倍。参与教师一致表示，宇航员（无论男女）是学生的重要积极榜样，并且ARISS计划对学生具有价值。与中学生相比，更多的小学生表现出积极的STEM兴趣变化。中学生对STEM学科兴趣的积极变化表明ARISS计划能够激励年龄较大的学生。本研究证实，ARISS计划对学生产生了显著且积极的影响，实现了计划与学校课程的结合。本研究对现有文献作贡献，后者聚焦于励志专家榜样对“追求STEM研究和职业的学生动机水平”的影响。

关键词：科学、技术、工程和数学，国际空间站，ARISS，情境认知，榜样

Introduction

From its inception in 1996, the ARISS program, through the cooperation of its international partners as shown in Table 1, has provided over 1,500 two-way radio contacts between orbiting astronauts and school students. In so doing, the ARISS program seeks to inspire students to pursue STEM based courses of study and careers, as well as providing opportunities to experience space to ground communication techniques through Amateur Radio.

Table 1: ARISS International Partners

Canadian Space Agency (CSA)
European Space Agency (ESA)
Japanese Space Agency (JAXA)
United States National Aeronautics and Space Administration (NASA)
Russian Space Agency (Roscosmos)
Radio Amateur Satellite Corporation (AMSAT)
Amateur Radio Relay League (ARRL)

The ARISS program is classified as an educational outreach and curriculum intervention activity. Outreach activities included in the school curriculum, presented by experts and outstanding role models, work together to provide an inspiring learning environment in which students develop autonomous motivation to enrol in STEM subjects and courses. This research project has confirmed the increase in student excitement and STEM interest levels, as observed by participant teachers, ARISS volunteers and students. This study, therefore, builds on existing STEM outreach intervention research, enhanced by the inclusion of the astronauts aboard the ISS as role models, situated within an inspiring educational setting, the ISS in outer space, and embedded in the school curriculum.

The purpose of this research is to determine the extent to which the ARISS Program is meeting its primary goal of enhancing school students' interest in STEM subjects and to analyse any changes in student interest towards STEM subjects and STEM based careers attributed to the ARISS program.

Research Question

The main research question is: *Does student participation in the ARISS program influence their interest in and selection of STEM subjects?*

This Central Research Question was broken down into three research sub questions:

Research Sub Question 1: What is the relationship between ARISS and interest

in STEM as indicated by student perspectives, opinions, and experiences?

Research Sub Question 2: Does evidence exists to support the notion that astronauts, as STEM role models, in low earth orbit aboard the ISS can provide the motivation to encourage student interest levels in STEM learning areas?

Research Sub Question 3: Is there a relationship between student age and interest in STEM as influenced by the ARISS program?

Literature Review and Conceptual Framework

Impact of STEM Activity

There is much discussion in the literature regarding the national and economic reasons for the development of STEM programs (Kelly, 2016; Rosenzweig, 2016; Vennix, 2018). However, the question regarding the value of STEM to the participating students is also important. Firstly, when STEM subjects are integrated and outreach activities and subject materials are perceived by participants as relevant and presented by strong role models, students develop autonomous motivation towards the study of STEM (Shin, 2016; Kelly, 2016). Secondly, other valuable characteristics are developed, essential for 21st-century skills acquisition such as digital age literacy, inventive thinking, and effective communication (Husin, 2016).

Role Modelling

The literature indicates that outreach activities and role modelling within STEM activities can provide a positive influence on student motivation, interest in and willingness to embrace STEM subjects and courses. For example, Rennie (2014) states Opportunities for learning science outside of school make a significant contribution to science education"(p. 120). Rennie goes onto describe the positive impact outreach programs have on student decision making to follow STEM courses of study and that involvement in outreach programs "… strongly related to career interest in Science, Technology, Engineering and Mathematics (STEM)" (p. 120).

The importance of role modelling in overcoming STEM related stereotypes is well documented in the study by Van Camp (2018), who observed that the successful STEM role model had "major" and "robust" STEM relationships and the use of a role model positively impacted the stereotypical STEM perceptions (i.e., a white male wearing a lab-coat) and the students' sense of belonging to the STEM world and motivation to embark on STEM careers. Given this impact, the introduction of a role model from the female gender, non-white ethnic groups or lower socio economic classes (Van Camp, 2018) can enhance motivation to pursue STEM subjects when the outreach activity is integrated into the curriculum. Rosenzweig & Wigfield (2016) support this by concluding that STEM stereotypes are generally negatively geared to the female gender, non-white

ethnic and low socio-economic groups, and positively geared to white males, thereby supporting the belief that only white males from upper socioeconomic groups can be successful in achieving a STEM based career.

The concept of role modelling was further tested during the UK Principia Mission (UK Space Agency, 2018). The main aim of the UK Principia Mission was to "Exploit the education and inspirational value of Major Tim Peake, the UK astronaut's mission to the International Space Station in 2015, which reached 20 million people via press and media interventions" (UK Space Agency, 2018, p.7). This study concluded that a robust link existed in reversing the downward trend in STEM interest and motivation (Rosenzweig & Wigfield, 2016). The Principia Campaign also revealed a strong statistical trend of student interest towards STEM with a consistent positive impact on student attitudes.

The FutureInTech intervention program (Williams, 2014) defines a role model as an "ambassador." The main goal of the FutureInTech research was to determine how influential a visiting STEM ambassador to the school is on the aspirations and attitudes of school students in terms of enrolment in STEM courses leading to future careers. This study went on to report that the greatest impact on students' STEM choices occurs when the interventions are conducted before the age of 14; that students make their choice to continue or to withdraw from STEM before year 10 and that consolidation of STEM attitudes towards continuing with STEM courses of study occurs in years 7 and 8. The FutureInTech study (Williams, 2014) also indicated that family and friends play a significant part in student attitudes towards STEM. As with other studies, (Williams, 2014) reports that role model (ambassador) interventions can be significant in STEM student decision making processes.

The dissertation by Bagiya (2016, p. 47) outlines the following fundamental constructs associated with the development of STEM outreach activities:

- The activity should be stimulating, practical and relevant.
- The activity should be Interactive.
- The activity should form part of an enriched curriculum, comprising informal learning and extracurricular activities.
- The activity should provide a way for disadvantaged students to engage in STEM.
- The activity should provide advice on STEM studies and careers.

The ARISS program is a good fit with curriculum intervention, role model-based programs as most students can identify with one or more astronauts over time through gender and national characteristics.

Amateur Radio on the International Space Station

The ARISS program can be classified as a role model-based intervention by providing students a live opportunity to speak to astronauts acting as STEM role models.

The goals of the ARISS program are:

1. *Inspire an interest in science, technology, engineering, and math (STEM) subjects and in STEM careers among young people.*
2. *Provide an educational opportunity for students, teachers, and the general public to learn about space exploration, space technologies, and satellite communications.*
3. *Provide an educational opportunity for students, teachers, and the general public to learn about wireless technology and radio science through Amateur Radio.*
4. *Provide an opportunity for Amateur Radio experimentation and evaluation of new technologies.*
5. *Provide a contingency communications system for NASA and the ISS crew.*
6. *Provide crew with another means to directly interact with a larger community outside the ISS, including friends and family.* (https://www.ariss.org/)

Participation in the ARISS program requires each school to complete the ARISS application documentation, which includes the development and inclusion of an education plan to demonstrate how the school will integrate the proposed contact into the curriculum. Through its insistence of the inclusion of an education plan as a component of the intervention event into the school curriculum, ARISS demonstrates its own understanding that this is an opportunity to make an impact in the STEM curriculum, maximising the value of the ARISS event in the academic lives of staff and students.

There are two methods of ARISS contact from which a school may choose to facilitate the ARISS event. The *Direct Contact* option is selected by a school where a member of staff possesses an Amateur Radio Licence or works in conjunction with an Amateur Radio Operator to build the required equipment at the school to establish and maintain a radio contact with the ISS. Where the technical expertise is not available at a school, the *Telebridge Contact* option is selected. The Telebridge Amateur Radio Stations are a small select group of Amateur Radio Operators located in strategic locations around the world and coordinated by the ARISS organisation. The school is linked to the Telebridge Station either through a direct telephone line connection provided by ARISS or through an online teleconference audio source. Both Direct and Telebridge Contact options must provide a ground station able to track the ISS as it passes over the ground station and provide radio transmit and receive signals to and from the telephone network.

ISS Orbital Specifications

The ISS orbits between 370–460 km above earth at a velocity of 27,500 km/h. When viewed from an imaginary observer, located at a fixed point above the earth in outer space, the ISS appears to revolve around the earth on the satellite orbit line shown in Figure 1. The

ISS can be thought of as a near-polar orbiting satellite with an orbital inclination set at 51.6 degrees measured at the equator, as shown in Figure 1:

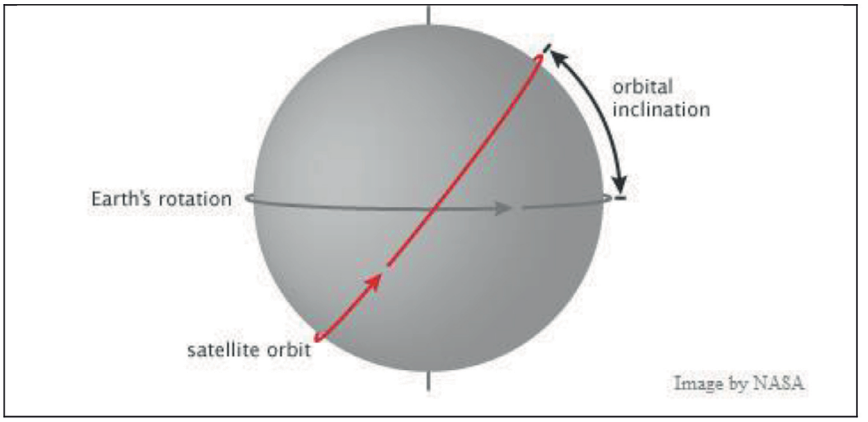


Figure 1: Orbital Inclination

Figure 2: VK6MJ Ground Station Antenna System

A directional antenna system, capable of azimuth and elevation motion, employed by the ground stations, such as the one seen in Figure 2, must be accurately steered using computer-controlled hardware. This enables the required precise tracking of the ISS permitting the ground station to maintain maximum transmitted and received radio signal strength during the ARISS event.

ISS Radio Contact

It is usual for the schools involved in the ARISS program to advertise the contact through their local TV and radio media outlets, and attendance invitations sent to Heads of State, government officials,

and other VIP personnel. Single school participation is the norm; however, combined multiple school contacts are not unusual in which more than one school share the ground station facilities with the schools linking together through an online teleconference system or conference call telephone link. The ARISS contact is usually a very important event on the school calendar resulting in an all-school presentation who observe and participate in the event which may be streaming live to the internet.

Once radio contact with the ISS is established, selected students read their own prepared questions and listen to the answers from the astronaut. The speed of the ISS provides an average space to ground contact time window of 10 minutes. Questions are kept as short as possible to maximise the time available and prior to the event the astronaut is emailed the list of questions to avoid the loss of time which would occur if the astronaut needed to have the question repeated for clarity. Depending on the complexity of the questions it is possible to have up to 19 or 20 questions delivered and answered before Loss of Signal (LOS), at which time the ISS has travelled beyond the visible horizon of the ground station.

Conceptual framework - Situated Cognition

Situated Cognition, as described by Kelly (2016), proposes that student learning is more effective when experiences are active, and explicitly situated in a relevant context. In the ARISS program, the students are actively engaged (Marshall, 2010, p. 53) with the astronaut, and the space program more generally through classroom activities. The context of space is explicit in both the intervention and in associated learning activities designed by the participating teachers.

A study by Vennix (2018) investigated the link between outreach programs, student needs fulfilment (described as student competence, relatedness, and autonomy), student motivation, and resultant attitudes towards STEM. Where the student needs were satisfied, as indicated by the students, an improvement in motivation was noted leading to improved attitudes towards STEM courses and careers.

Using Vennix's Situated Cognition outline, the learning environment can be equated to the school and its embedded ARISS program as indicated in Figure 3 where the top row is Vennix's outline, and the bottom row is the adaptation of the model to this research.

Given that a fundamental element of Situated Cognition is active engagement with relevant content, a strong link with the conceptual framework by Vennix (2018) can be established. The Vennix framework is therefore a good fit (Figure 3) when the learning environment is composed of the school curriculum with its embedded ARISS intervention consisting of an active live contact with an astronaut in the relevant setting of the ISS in low earth orbit.

This research expands the body of knowledge regarding STEM motivation and education by indicating

that when couched in the knowledge of how STEM concepts are applied to real world contexts and how these concepts interact with each other, then student learning which is relevant and authentic is enabled.

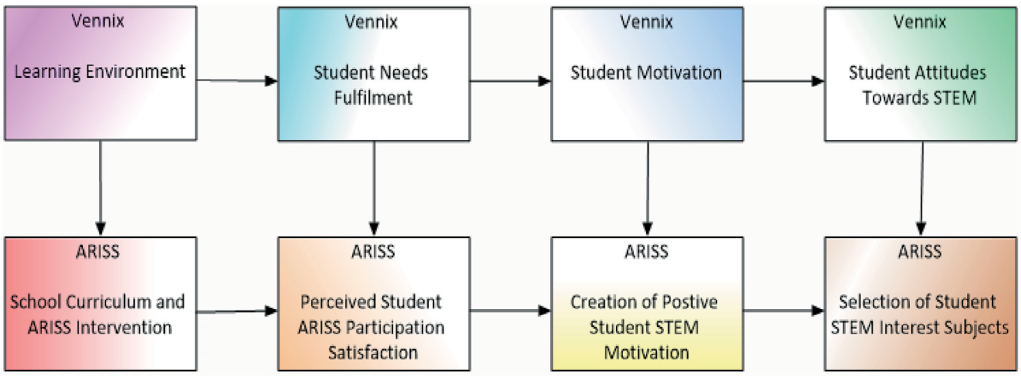


Figure 3: Situated Cognition ARISS Relationship

Methodology

This study employed a mixed-methods, multiple-case study design to develop an understanding of the nature of the ARISS program and its capacity to create positive motivation and interest in students towards the selection of STEM courses and careers. The case study methodology is selected for its usefulness in framing a comprehensive and intensive analysis of a social phenomenon (Harrison, 2017). Furthermore, the case study is able to accommodate a "mix of qualitative and quantitative evidence" (Yin, 2009) and lends itself to a mixed methods research design.

Identification of the Sample

Participant schools were selected from the operational ARISS school application lists followed by a formal invitation to the school to participate in this research. Access to these lists was granted by ARISS through the researcher's role as an Australia-based ARISS Telebridge Ground Station, callsign VK6MJ. This represents a convenience sampling technique as the schools apply to participate in the ARISS program and not as a result of the researcher looking for schools willing to participate in the ARISS program. The Case Study schools involved were from Canada, Germany, and the USA, producing a combined total of 296 participants.

The data collection process involved the following:

1. Schools apply for selection into the ARISS program through the ARISS website. Once the required documentation is provided by the schools, they go on to the ARISS waiting list.

2. Schools on the ARISS contact waiting list are invited to participate in this research.

3. Principals are sent invitation documentation which provides access to the questionnaires; a description of the research purpose and method; and the permission form for signing.

4. School Principals provide participant names for the creation of online questionnaire student and teacher accounts.

5. The pre-ARISS contact questionnaire is made available online to students and teachers.

6. Participation by the schools in the ARISS event with the astronaut.

7. The post-ARISS contact questionnaire is made available online to students and teachers.

8. A questionnaire is offered to participating astronauts where possible after return to Earth and to ARISS volunteers when convenient.

9. Video conference interviews are arranged and conducted with participating astronauts, teachers and ARISS volunteers.

Development and Administration of the Instruments

Two hybrid questionnaires consisting of both quantitative and qualitative questions were made available before and after the ARISS-contact to students and teachers. The pre-ARISS contact questionnaire was designed to gain an understanding of the students' base line or entry level STEM interest which existed prior to the ARISS intervention. The post-ARISS contact questionnaire, designed to revisit student STEM interest levels after the ARISS event sought to identify changes in student thinking regarding STEM interest. The same qualitative Likert scale questions were included in both pre and post contact questionnaires to measure relative changes in participant STEM interest.

Each questionnaire was limited to 20 questions to reduce participant fatigue and to encourage school participation by minimizing the time needed to complete each questionnaire, thus facilitating the inclusion of the instruments into the usual busy school curriculum. The questionnaires were originally composed in English and translated into the first language of the school students if requested; translations into Italian, Spanish, and German were conducted.

The questionnaires were initially assessed by the researcher's supervisory team and then piloted using the first two case study schools to check for any anomalies not previously considered.

Data Collection

Data were collected using the following process:

1. Individual students, teachers and ARISS volunteers log in to the questionnaire via the internet using the internet address and access details provided by the researcher.

2. All default passwords are changed by the participants to secure each individual's data.

3. At a convenient time to the school and just prior to the ARISS contact students and teachers complete the online Pre-Contact Questionnaire.

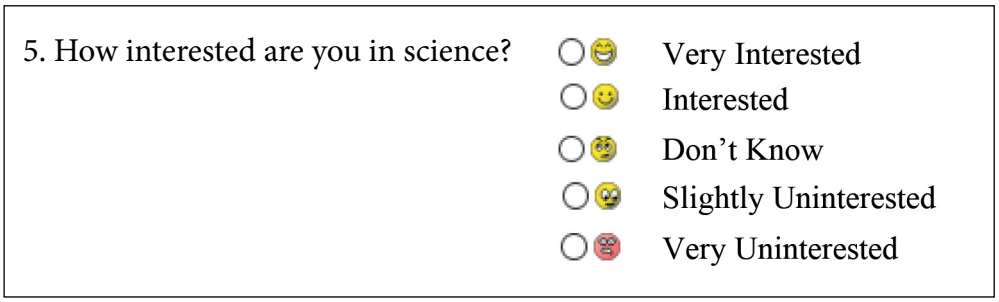
4. At a convenient time to the school and just after the ARISS contact students and teachers complete the online Post-Contact Questionnaire.

5. At a convenient time and independent of the ARISS event schedule, the ARISS volunteers complete the online ARISS Volunteer Questionnaire.

Online Questionnaires

Student Pre-ARISS Event Questionnaire

Specific to the individual questionnaires were those fields related to the student *interest* levels associated with the pre-event STEM learning areas, i.e., Science, Technology, Engineering, and Mathematics for which the student would select from the Likert responses, such as:



An indication of the student's level of *excitement* regarding the proposed ARISS contact was also sought through similar Likert responses of "Very excited," "Excited," "Not Sure," "Slightly Unexcited," and "Very Unexcited."

Student interest regarding their preferred adult careers was sought through both closed and open-ended qualitative questions. Student subject aptitude was sought through questions eliciting the student's favourite and least favourite school subjects, as well as the subject in which the highest grades are achieved for later comparison with the same questions presented in the post contact questionnaire designed to search for any changes due to the impact of the ARISS intervention. Finally, two questions regarding the student's level of anticipation of the ARISS event including a question of their own to which they would like to present to the astronaut if given the opportunity prior to the event completed the pre-event questionnaire.

Student Post-ARISS Event Questionnaire

The post-event questionnaire was specifically designed to reveal any changes in the student's STEM subjects interest levels compared with the STEM interest levels given in the pre-event questionnaire. This was accomplished by revisiting the STEM interest level questions

from the pre ARISS-contact questionnaire seeking any changes that may have been caused by the ARISS event and to indicate which STEM learning areas reflected a change in student STEM Interest. The questionnaire also asked the student to share any question they would like to ask the astronaut if an opportunity arose to present it. The subject content of such a posed student question was sought and designed to provide an insight into student learning as a result of participation in the ARISS intervention. Finally, questions were presented regarding the value of the ARISS program through the naming of the best three things enjoyed by the student, a direct open-ended question as to whether the ARISS intervention was worthwhile, and a general comment regarding what was learned through participation in the event.

Teacher Pre-ARISS Event Questionnaire

Two online teacher questionnaires were presented, one prior to and one after the ARISS event. A Pre- and Post-test model was used to identify changes to teacher characteristics which may have been due to the impact of the ARISS event on the curriculum.

Teachers were asked to describe their role in the school, and the reasons for their and the school's participation. Further comment was sought describing how the ARISS event was incorporated into the curriculum and on the perceived student benefits as a result of the school's participation. Comments addressing the value of the ARISS event and a description of what the teacher considered to be evidence to support this were invited. An understanding of the degree to which the teacher included STEM studies in the curriculum was sought by requesting a brief description of how this was implemented by the teacher. This information provided the basis for a comparison with the data gained through the post event questionnaire to develop an understanding of the impact on teachers by the ARISS event.

Teacher Post-ARISS Event Questionnaire

The post-event questionnaire was specifically designed to seek any changes in the teacher's STEM interest, willingness to include STEM instruction within the curriculum, and to gather teacher observations on the impact of the ARISS program on the students and the school. Teachers were also asked to indicate if their school's initial reasons for participation in the ARISS event were confirmed, and to provide any comments regarding any changes or additions to the classroom activities as outlined in the pre-event questionnaire. Teacher opinions were sought regarding the effectiveness or perceived value of an astronaut as a role model with the aim of encouraging students to study STEM subjects.

ARISS Volunteer Questionnaire

A background information questionnaire was developed to seek data on the impact of the ARISS program from the viewpoint of those who are essential to the successful implementation of the event, i.e., the ARISS volunteers. Similarly, as with the teacher and student

questionnaires, the login data provided the identification details of the participants, such as name and location.

The ARISS Volunteers are those people who freely give of their time, expertise, and equipment to make the event happen. Volunteers create the contact schedules by liaising with the astronauts and space agencies, schools, Amateur Radio ground stations, mentors, phone companies, etc.

Initially this questionnaire records the volunteer's name, Amateur Radio callsign, role within ARISS and time spent as a volunteer. The main purpose is to develop an idea of how the ARISS program is perceived by the volunteers. The Volunteer is asked to forward an opinion as to the most important function of the ARISS program and to outline the most exciting experience encountered as well as that which has surprised the most including a description of the one thing that has remained foremost in memory. Specifically, a description of student and school feedback regarding the ARISS program in terms of its value is recorded. Finally, a tick box response to indicate a willingness to take part in an online video interview with the researcher was sought.

Data Analysis

Quantitative – Questionnaire Likert Scale Analysis

Each questionnaire is based on a hybrid design comprising of both ordinal and descriptive data. The corresponding Likert Scale questions regarding student interest and excitement levels were converted to numerical values with the greatest value (5) representing a "Very Interested" response through to the value (1) representing a "Very Uninterested" indication of student interest in the STEM learning areas and were analysed using a t-test statistical treatment procedure.

Table 2: Combined Case Study Schools ARISS Event Significance Analysis

Response Means	Science	Technology	Engineering	ARTS	Mathematics
Pre-Contact	3.99	4.05	3.80	3.37	3.82
Post-Contact	4.17	4.15	3.98	3.48	3.88
Significance	0.03	0.22	0.11	0.27	0.32

Table 3: Percentage Change in STEM Interest Means from Pre-event to Post-event

	Science	Technology	Engineering	ARTS	Mathematics
Very Interested	26%	-2%	11%	12%	11%
Interested	3%	24%	13%	-3%	-4%
Don't Know	-43%	-32%	-14%	13%	-12%
Slightly Uninterested	-7%	-13%	-29%	-23%	39%
Very Uninterested	*-100%	*-100%	-67%	-6%	-34%
* 100% decrease in participants selecting "Very Uninterested"					

Using the pre-questionnare mean as a baseline, the post- mean was used to test for any change in student STEM interest due to the ARISS event and indicated as a post event percentage change. When the results are examined from a *continuous measure* point of view (Sullivan, 2013) as shown in Table 3, a positive trend in the change of STEM interest response can be seen within all learning areas. Here, it is noted, within Science, there is a positive trend of 29%, Technology at 24%, Engineering at 24%, ARTS at 12%, and Mathematics at 11% after the conclusion of the ARISS event. The students, at the time of the presentation of the pre-contact questionnaire, exhibited high STEM interest levels due to class activities over the preceding months and in anticipation of the forthcoming ARISS event. Therefore, as indicated by the STEM interest response means in Table 2, where the initial pre-event score is already high, difficulty to show a significant improvement in the post event score could be encountered, even in the presence of percentage change improvement.

Four schools were selected as case studies. Table 4 presents the student and teacher participation numbers from each school.

Table 4: Case Study School Questionnaire Participant Numbers

School	Students		Teachers	
	Pre.	Post.	Pre.	Post.
USA (1)	20	13 (65%)	5	3
Germany (1)	103	35 (34%)	2	0
Germany (2)	14	13 (93%)	1	1
Canada (1)	86	48 (56%)	4	4

Where high numbers of pre-event participants exist, i.e., Germany 1 and Canada 1, we can see an apparent difficulty in maintaining similar numbers of post-event participants in which 34% of Germany 1 and 56% of Canada 1 participants return for the post-event. Conversely the schools with smaller overall numbers of participants exhibit greater post-event participation rates, i.e., USA 1 at 65% and Germany 2 at 93%. It is postulated that schools with smaller participant numbers are more likely to have fewer student access

constraints and an improved ability to provide access to the post-event questionnaire.

Data from the pre- and post-questionnaires were analysed by treating the pre and post questionnaire data as independent samples. Paired t-tests were not used due to the large number of unmatched pre and post respondents, largely due to school attendance and Covid related issues. Using the mean of the pre-questionnaire ordinal data as the standard hypothesized mean, it was possible to use the post-questionnaire results as the independent variable and to seek any significant changes in student STEM interest regarding the effectiveness of the ARISS program as a catalyst for increased levels of student interest in the STEM learning areas.

To better understand the impact of the reduction in post-event participant numbers on the results, a trend analysis was conducted and contrasted with the unmatched pairs independent variable analysis using a data subset collated from the combined matched pairs of Germany 1 and Canada 1 where the post questionnaire participation rates were low. From this combined sample of 63 participants, the change in interest level direction produced a positive trend in STEM interest, similarly to the trend of the independent samples' method presented in Table 3. From the matched pair analysis, we find the positive paired trend results for Science is 20%, Technology at 15%, Engineering at 25%, ARTS at 25%, and Mathematics at 12%. These results tend to support the findings of the independent samples analysis, namely the post event positive increase in interest in all subjects.

Student Question Prior Subject Knowledge Analysis

Evidence of subject knowledge found within the student's question and therefore evidence of learning through the ARISS program, was sought, which indicates a deeper student understanding of the subject concepts used to form the question presented to the astronaut. A total of 110 student questions from the case study schools, and a further 166 student questions from 10 randomly selected non-case study schools were presented to a panel of three experienced teachers who, using the procedure by Davis (2010, p. 52), conducted an analysis of each question to determine the presence of such prior knowledge behind the composition of each question. Simply put, did the question show evidence of student knowledge or learning about the ISS or outer space in general, or could the question be asked by anyone without any knowledge of the ISS or outer space? Each question's assessment was entered into a spreadsheet and an assessor majority response was used to create a marking key.

An average student question knowledge content level of 73.5%, based on all student questions, comprising 72% Primary School and 75% Secondary School data, pointing to a positive pre-knowledge component of the posed student questions was achieved, which is significantly close to that of 74% of questions showing the existence of prior knowledge found in the original procedure by Davis (2010, p. 52).

Table 5: Case Study Schools Student Question Prior Subject Knowledge Content

Case Study Schools	**Student Question Content**
Secondary School Germany 1	68%
Secondary School Germany 2	67%
Primary School USA 1	70%
Primary School Canada 1	85%
Non-Case Study Schools	
Primary School Canada 2	70%
Secondary School Russia 1	60%
Technical High School USA 2	100%
Primary School USA 3	95%
Primary School Russia 2	67%
Secondary School USA 4	69%
Junior High School Canada 3	67%
Secondary School Israel 1	95%
Primary School Argentina 1	56%
Primary School USA 5	58%
All primary Schools:	**72%**
All secondary schools:	**75%**
All schools:	**73.5%**

The wide range of prior knowledge content scores, as shown in Table 5, indicates the degree to which schools guide the composition of questions, from a highly technical viewpoint, as indicated by the USA 2 school, to giving students free rein in question composition as seen in the Argentina 1 school prior knowledge content scores.

The remaining primary schools present a greater degree of teacher influence within the question composition process. Generally speaking, according to the submitted education plans, secondary school students tend to be given more freedom than primary students to develop their own questions, followed by a voting process to select the questions to be used.

Qualitative Data Analysis

The qualitative analysis of this research imported data from the open ended, or non-Likert scale data, collected by the online questionnaires presented to students, teachers, and ARISS volunteers.

An eleven-step content analysis process as described by Cohen (2018, p. 676) was implemented:

Step 1: Definition of the research questions.

Step 2: Selection of the texts for sampling.

Step 3: Selection of the sampling process (in this case convenience sampling).

Step 4: Defining the context of document generation (i.e., interviews, open ended questionnaire responses).

Step 5: Selection of units of analysis (i.e., words and phrases as themes).

Step 6: Definition of analysis codes.

Step 7: Creation of analysis categories.

Step 8: Perform data coding and categorisation.

Step 9: Perform data analysis – *including the use of triangulation of methods and sources*.

Step 10: Summary.

Step 11: Development of speculative inferences.

Analysis of student qualitative questionnaire responses

Through the use of deductive coding the level of student interest in, or positive attitude towards, the ARISS event was observed to be very high in which student responses indicated strong engagement in both the pre and post event questionnaires. Thematic coding was applied to the samples to determine the subject or interest areas in which the student found the greatest engagement through the use of student created themes generated from their responses to the open-ended questions in both pre and post ARISS event questionnaires.

Thematic content changes can be seen when comparing Figures 4 and 5 in which the interest levels change within common themes and previously unseen themes appearing after the ARISS event as shown in Figure 5. Generally, the post-ARISS event shows an increase in the themes associated with the astronauts on board the ISS and the science behind the maintenance of the ISS in low earth orbit. Themes related to a more general discussion of outer space are more noticeable in the pre-ARISS thematic analysis as contrasted with the more specific ISS related themes found in the post ARISS thematic analysis.

Teacher Observation and Feedback Analysis

Teacher observations and feedback were also analysed using deductive and thematic coding. Initially all teacher questionnaire responses were divided into pre- and post-ARISS event groups and analysed in which the teacher concepts were used to research these themes. Teacher comments were all very positive and supportive of the ARISS program. For example, as one teacher put it:

> "Students had a once-in-a-lifetime opportunity to be part of

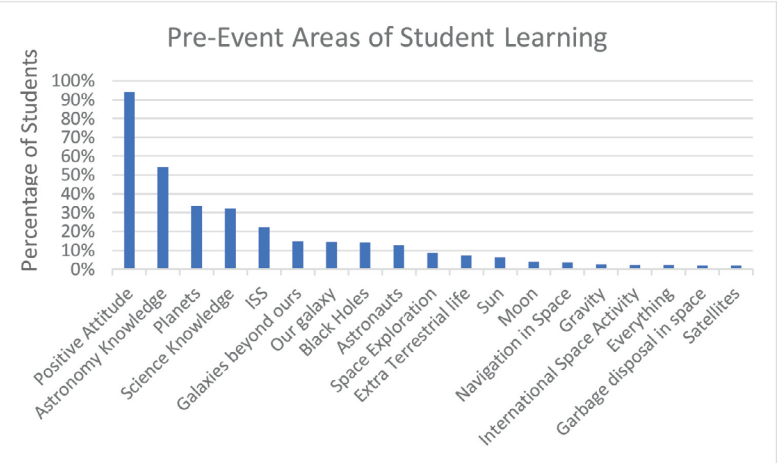


Figure 4: Pre-ARISS Event Thematic Coding

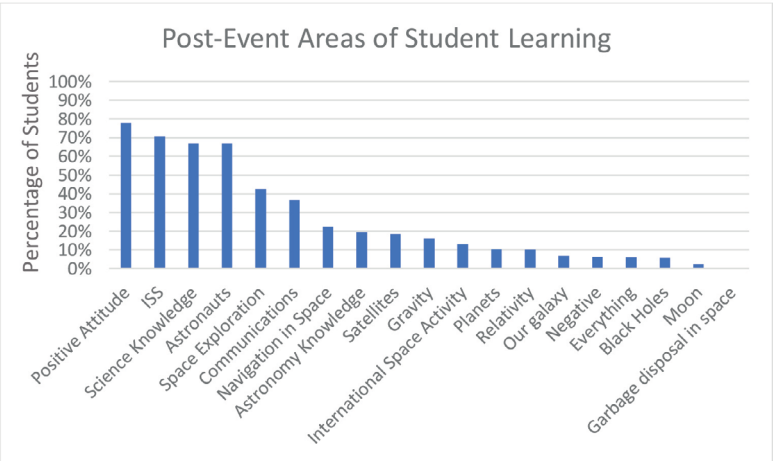


Figure 5: Post-ARISS Event Thematic Coding

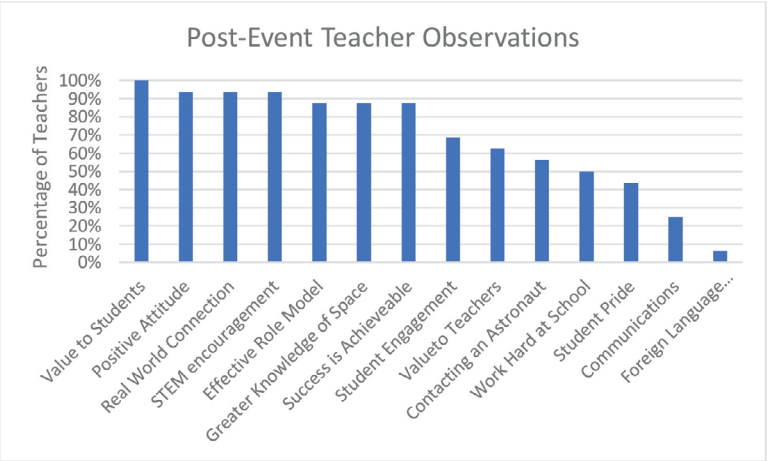


Figure 6: Post-ARISS Event Teacher Observations Thematic Coding

> history. They had a personal connection to the launch and the experiences of the ISS astronauts. Their eyes were opened to the science and the efforts involved in space travel. It was an experience they are unlikely to forget." (Participant Teacher, Online Questionnaire)

When asked to comment regarding the nature of the evidence indicating the value of the ARISS program, another teacher reported the value ARISS, NASA, and the ISS placed on her students:

> "… the coordination between the school, ARISS volunteers, NASA, and the ISS. The value that all of these groups are placing on our students." (Participant Teacher, Online Questionnaire)

The thematic codes generated from the analysis of the teachers' data, represented in Figure 6, point to high scores as generated by the ARISS program in relation to the value of ARISS to students. In this regard teachers were very positive and indicating the ARISS program was similarly worthwhile in encouraging student STEM interest.

Findings

This research sought to develop an understanding of the degree to which the ARISS School Program influences the STEM interest and motivation levels of its participant students and teachers. The importance of astronauts as STEM role models was investigated and an understanding of role model suitability of an astronaut in low earth orbit aboard the ISS to school students was explored. A non-intrusive, and easy to administer instrument was developed which successfully gathered the required data from the school students, teachers and ARISS volunteers. This instrument performed proficiently and produced data which were valid and reliable supported by Cronbach's Alpha at 0.82 pointing to a very high reliability of the quantitative sections of the pre- and post- questionnaires.

Across the case study schools it is noteworthy the male to female ratio of participants was close to 2:1. From the pre- and post- questionnaires this gender difference is apparent with male STEM interest peaking higher than that of STEM interest indicated by females. An initial high student level of enthusiasm towards STEM interest prior to the ARISS event was detected which provided a high STEM interest entry baseline which in turn made it difficult to measure any significant changes in student interest level towards STEM due to participation in the ARISS event. This impacted the t-test results of the quantitative questions with only Science indicating a significance of 0.03 using an alpha of 0.05, and only small effect significance with Cohen's D results for Science and Engineering as seen in Table 6.

Table 6: Quantitative Questions Significance

STEM Learning Area	p value	Cohen's D	Alpha = 0.05
SCIENCE	0.03*	0.21**	
TECHNOLOGY	0.22	0.1	
ENGINEERING	0.11	0.2**	
ARTS	0.27	0.08	
MATHEMATICS	0.32	0.06	
* = significance		** = small effect	

This observed high level of pre-event excitement is supported by the following post-event teacher observation:

> "STEM is already very popular at our school, with a K through 8 program already established. Our schoolwide focus on space this year, and the anticipation of the ARISS contact, made them even more enthusiastic about STEM." (Participant Teacher, Online Questionnaire)

Very high ARISS excitement levels were exhibited by all case study schools. The Likert scale results associated with the level of student excitement is indicated by the following student numbers for each Likert choice:

> Very Excited = 42%, Excited = 28%, Don't Know = 20%, Slightly Unexcited = 8%, Very Unexcited = 2%, which results in 70% of students registering as Excited or above with female excitement registering at 64% and male excitement levels at 74%. All case study schools exhibited high levels of interest towards the STEM learning areas and a comparative reduced level of interest towards the ARTS, prior to the ARISS event, and a further decrease in ARTS interest post-event.

An analysis of positive changes in student STEM interest found in the post event questionnaire indicated there were twice as many students reporting an increase in STEM interest than the number of students experiencing no change in STEM interest at the conclusion of the ARISS event.

All post-event questionnaire participant teachers unanimously reported that astronauts, both male and female, are a significant positive role model for school students, and all teachers, pre- and post- questionnaire participants, were similarly unanimous in their belief that the ARISS program was valuable to their students. From the ques-

tionnaires a figure of 88% of primary and 97% of secondary students indicated the presence of learning occurred as a result of their participation in the ARISS program. The analysis of subject content within the questions created by the students to be presented to an astronaut, however, was lower than the figure derived from the questionnaires, with the average subject content of primary school questions indicated 72% of the questions exhibited learning, and secondary school subject content at 75%. The total average of all schools equates to 73.5% of student questions indicating subject content which is significantly close to that of 74% of questions showing the existence of learned knowledge found in the original procedure by Davis (2010, p. 52).

From the perspective of a comparison between primary and secondary age groups, more primary aged students exhibit a positive interest change than secondary age students. This change in STEM interest supports the findings by Williams (2014) in which the greatest impact on students' STEM choices occurs when the interventions are conducted before the age of 14 and as such changes in STEM interest will occur before such an age.

Volunteer interviews reported, anecdotally, that many schools which provide their own direct contact are generally more motivated towards the ARISS event than many of the schools opting for the telebridge contact option.

Limitations

An approximate 50% reduction in student numbers returning to complete the post event questionnaire possibly due to the end of the ARISS event at the school was observed. The Covid Virus Impact has been very significant in the number of schools postponing their contacts with the ISS until a future time when the risk of Covid infection has declined. Those schools which have completed their contacts have operated in a student isolation format forcing students to stay at home. ARISS participation was made possible through the use of online video conference applications also known as 'multi-point' contacts. In many instances the online questionnaires were also accessed by the students from their homes and largely only by those students directly involved in the event and in communicating with the astronaut rather than a larger school sample which could be expected where normal student attendance rates would apply. Subsequently, for some schools, this led to a decrease in data sampling as only those students involved in the live event were given the opportunity to participate in the data gathering exercise.

Conclusions

The case study schools were selected from the ARISS event school application lists from which the perspectives, opinions, and experiences of students and teachers were collected through the development and presentation of a pair of online, hybrid pre- and

post-ARISS event questionnaires consisting of both quantitative and qualitative questions. Data were also extracted through the analysis of the subject content of the posed student questions developed by each school to be presented to the astronaut during the ISS contact event. Data triangulation was employed through the combination of the quantitative and qualitative student responses, teacher observations and the analysis of the subject content of the posed questions created by each school for use in the ARISS event.

Research Sub Question 1: *What is the relationship between ARISS and interest in STEM as indicated by student perspectives, opinions, and experiences?*

We discovered the existence of high levels of student and teacher excitement and heightened STEM subject interest levels generated by the anticipation of a contact with the ISS through the steady preparations conducted by the schools and ARISS program leading up to and including the ISS contact. Superimposed on this high student STEM excitement entry level was a positive trend in the change of STEM interest response within all learning STEM areas as a direct result of the climactic ISS contact where students were able to speak to an astronaut and asking a prepared question.

Research Sub Question 2: *Does evidence exist to support the notion that astronauts, as STEM role models, in low earth orbit aboard the ISS can provide the motivation to encourage student interest levels in STEM learning areas?*

Teacher feedback obtained through the analysis of the teacher qualitative pre- and post- event questionnaires indicates a strong belief that astronauts provide outstanding examples of role models for their students through the provision of very high levels of motivation regarding the achievement of personal goals and interest in pursuing STEM subjects at school.

Research Sub Question 3: *Is there a relationship between student age and interest in STEM as influenced by the ARISS program?*

The relationship between student age and STEM interest has confirmed historical research where the greatest impact on student interest change occurs within the primary school age students. The ARISS program shows very high levels of student attitudinal changes in primary school aged students and a slightly reduced impact on high school aged students. However, the change in secondary school age students is nevertheless strong, indicating the ability of the ARISS program to influence older students.

The main research question is: *Does student participation in the ARISS program influence their interest in and selection of STEM subjects?*

Given the primary goal of the ARISS program is to enhance school students' knowledge of, and interest in, STEM subjects and their subsequent motivation to pursue STEM subjects by providing an exciting opportunity to speak to astronauts acting as STEM role models, it is possible to determine

the degree of goal achievement of the ARISS program.

This research confirms that the ARISS program has a significant and positive impact on students, through the achievement of its goals, where an integrative partnership with the school curriculum is achieved. This research has contributed to the existing literature surrounding the impact of inspirational expert role models on the motivation levels of students to pursue STEM based studies and careers.

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