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The Attitudes of Tongan Senior Secondary Students Toward Science

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Abstract

As with other Pacific Island nations, the scientific efforts of the Kingdom of Tonga have been hampered through a lack of local scientists and science graduates. As observed globally, the region appears to face a steady decline in student interest and achievement in science, resulting in reduced uptake of science subjects in schools and universities. This study aims to provide insight into the attitudes of Tongan senior secondary students toward science, using the validated Test of Scientific Related Attitudes (TOSRA) instrument. The sample population comprised 2636 students of approximately 15–18 years of age, from 26 schools across Tonga. Overall, the mean attitudes of Tongan senior secondary students toward science were lower than that previously observed for Australian secondary students (Grades 7–10) and Fijian senior secondary students. A significant reduction in attitude was found between forms 5 and 6 for female students from rural areas, but not those from urban areas. No significant changes across different form levels were found for male students. The greatest difference between students' perspectives was found for the normality of scientists, which may be indicative of cultural views toward this topic. Combined with the similar results of previous research in Fijian students, this may point toward broader differences in the attitudes toward science between students in Pacific Island countries more generally.

Keywords Test of Scientific Related Attitudes (TOSRA) · Gender · Senior secondary students · Science education · Pacific Island Countries

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Introduction

Science Education: A Global Perspective

As we become increasingly globally connected with an ever-expanding wealth of scientific research and technological expertise, both opportunities and challenges expand exponentially. In order to keep par with these rapid advancements and facilitate concerted efforts towards scientifically justified decision-making and knowledge-based innovation, a solid foundation and understanding of science and technology is required. As such, it is imperative that a range of stakeholder groups from government, professionals, enterprise and industry are able to contribute to discussions at all levels of curriculum development, allowing all parties to contribute to, learn and benefit from the process (Hazelkorn et al., 2015). This is particularly important given that both globally and particularly in Europe, there has been an increase in the numbers of students leaving formal education with science qualifications over the last decades (Charbannier & Vayssettes, 2009; Smith, 2011; Trumper, 2006). However, the numbers of students expressing interest in pursuing science-related careers has stagnated, leading to a shortage of science-based innovations and entrepreneurship (Naiker et al., 2020; Sjøberg & Schreiner, 2010). The end result has been a massive unprecedented shortfall in people with a practical knowledge of science across all levels of society and the economy (Broggy, 2017; Kirby & Cullinane, 2017).

Nevertheless, science continues to be an innovative, problem-solving discipline that forms an increasingly essential part of our lives (Naiker & Wakeling, 2015), highlighting some serious challenges in the area of science education that need to be addressed globally (Kennedy et al., 2014; Naiker et al., 2020). The Pacific Island Countries (PICs) are not immune to this challenge as they continually strive to improve their standing in the scientific community, both within from the Oceanic region and globally (Naiker et al., 2020). However, in many instances, limited resources and a lack of public and private-sector jobs in science-related disciplines may present a considerable obstacle toward encouraging interest in science in educational settings (Brown et al., 2014a). Furthermore, low wages for essential science related jobs such as those in the education and health sectors are added factors that have been a constant discouragement for the study of pure sciences in the PICs (Sharma et al., 2018a). Finally, this problem is compounded by a lack of qualified science teachers, largely due to the aforementioned low wages and/or monetary gain associated with such crucial positions.

Background of the Tongan Schooling System

Education systems have been significantly transformed in the South Pacific coming into the twenty-first century. As stated by Thaman (1995), education systems in this region were more or less informal prior to the arrival of Europeans in the 1600 s. Skills were passed on according to gender and status in the community,

with the extended and communal family largely being responsible as the primary institution for teaching moral principles and virtues (Paongo, 1996). The early explorers from Europe introduced formal education to PICs not as their first priority, but rather as a contributing element for their own endeavours and missions (Thaman, 1995).

The colonizers of the PICs were vested with gaining 3 key motives—economic, political and religious—with the relative weightings of these factors varying between different Islands or periods of colonization (Thomas & Postlethwaite, 1984). The Kingdom of Tonga, named as the Friendly Islands of the South Pacific by Captain Cook, is unique in that it was never colonized by any European country; although it was under the protectorate status of Great Britain for about seventy years between 1900 and 1970 (Farmer, 1855; Thomas, 1984). Thus, formal education was not introduced into Tonga as a result of colonization, as was the case in other PICs such as Fiji.

The introduction of missionaries to Tonga following European explorers in the 1600 s slowly carved the path toward a formal education system (Paongo, 1996). The first missionaries, belonging to London Missionary Society, landed in Tonga in 1797 (Ministry of Education, 2010). Since the primary aim of education was to allow the Indigenous populace of Tonga to read the Bible, the study of the English language was central, resulting in the construction of schools to provide a more classroom-based learning and teaching setting (Paongo, 1996). It is not far-fetched to say that in these early days, education and being able to read the Bible complemented each other in many ways. The first official school was established on 17 March 1828 (Ministry of Education, 2010) and over the next 4 decades, many prominent schools were established with a new set of curricula vastly different to that taught during the informal education system (Paongo, 1996). Primary schools were initially built, with secondary school following later (Paongo, 1996). The Wesleyan Mission established the first secondary school in Tonga in 1866 in response to the growing need of the newly constituted government (in 1862) for civil servants as well as church ministers and religious instructors (Ministry of Education, 2010). In conjunction with the moral values and Christian religion, this new form of education increasingly incorporated literacy, numeracy and writing skills in order for the populace to better understand the expectations and implications of their newfound religion and faith (Ministry of Education, 2010). Hence it can be safely concluded that formal education system was brought into Tonga due to religious reasons and its introduction brought colossal changes amongst the Tongan community.

The nation of Tonga comprises 172 islands, out of which only 36 (21%) are permanently inhabited (Central Planning Department, 1991). The current population of Tonga is around 104,000 (World Bank, 2020). The islands are divided into three main island groups—Vava'u, Ha'apai and Tongatapu, possessing a total land mass of approximately 747 square kilometres (UNESCAP, 2000). The wide spread of the islands—800 km in a north–south direction—created significant logistical difficulties for the government to effectively equip and resource schools in the more remote islands. This resulted in the establishment of most secondary schools on the largest and most populous island, Tongatapu, largely accounting for the population drift to Nukualofa, the capital of Tonga situated in Tongatapu (Thomas, 1984).

The medium of instruction initially begun in the Tongan language but then progressed to include English—not only to facilitate communication between the two worlds, but also to better understand and disseminate the implications of religious teachings. To this day, this method of bilingual education continues to be commonly practiced in the Kingdom for primary and secondary education, which possesses both strengths and weaknesses (Carpenter & Taumoefolau, 2014; Lotherington, 1998). Interestingly, we also note that students of Tongan ancestry form one of the fastest growing groups in New Zealand, leading to the latter's Ministry of Education publishing resources in Tongan language every year for its early childhood centres and schools (Ministry of Education, 2000).

The Tongan education system has been governed by a number of Acts, Frameworks and Commissions, including the first Act of Parliament chartered in 1876 and revised in 1882, the Education Act of 1927 and subsequent amendments, the Tonga National Commission established in 1984, Strategic Plan for Education in Tonga (2003–2013), Tonga Education Policy Framework (2004–2019) and the Tonga Education Support Program from 2005. Between the 1970s and the present, primary education has largely been a government affair whereas secondary schools are divided into Government and Church-led schools (Thomas, 1984). Towards the end of the 1960s, there came the only private educational establishment,'Atenisi Institute, founded by the late Futa Helu.'Atenisi had two divisions consisting of a high school and a university that offered Bachelor-level courses recognised by universities in New Zealand and Australia (Thaman, 1988). Aside from being a private institute with its own Foundation for Performing Arts division, it offered courses and programs in the arts and sciences (Catherwood et al., 2003).

The Decline of Interest in Science

Globally, studies and reports show a lower student achievement in science and declining student interest in science (Kirby & Cullinane, 2017; Naiker et al., 2020; Smith, 2011), particularly among secondary school students (Potvin & Hasni, 2014; Turner & Ireson, 2010). A similar reduction in interest has been reported in PICs (Dakuidreketi, 2014; Sharma et al., 2018a). These trends correlate closely with the steady decline in enrolment in the science subjects in secondary schools (Dakuidreketi, 2014) and science programmes in higher education (Pasikale et al., 1998; Sharma et al., 2018a) and low achievement in science subjects (Sharma et al., 2018a) in the South Pacific. A study by Barmby et al. (2008) on English students between ages of 11 to 14 found an overall decline in the attitude toward science as students grew older, with a greater decline found amongst female students. These authors highlighted a range of reasons identified for this decline, including science being perceived as not practical, not relevant, or not well explained.

While there are numerous reasons proposed for the decline of scientific interest in the literature, the ones most applicable to Tonga include: low motivation for science driven by lack of advocacy from family and society, poor infrastructure, lack of qualified science, mathematics and Information Technology (IT) teachers, IT competencies, community mobility, skewed job market demands, foreign education

material and resources, the nation's priority areas, and the students attitude, perception and readiness towards science and IT (Reddy et al., 2017; Sharma et al., 2018a, 2019b). Often students from rural regions have poorer access to high quality education resources; hence could be expected to have poorer attitudes toward academic subjects such as science. However, Astalini et al. (2020) demonstrated that amongst Indonesian students, those from rural areas displayed slightly more positive attitudes toward science compared to those from urban areas. This difference was tentatively attributed to greater support from their family to pursue science-related subjects, in addition to their involvement in more hands-on experimental-type activities in their daily lives, compared to urban students.

The other aspect that requires close attention in dealing with decline in scientific interests is the impact of development/donor aid on the decisions and discussion around curriculum design which are heavily influenced by donor partners and Western ideas of what constitutes science and /or STEM. In the context of Tonga, the question of whether donor countries such as Australia actually do assist with education depends on the sectors to which the donor country prioritises compared to the recipient country, and even more importantly upon what other donors are doing (Ware, 2007). As such it becomes apparent that PICs such as Tonga have a greater influence in advocating their immediate needs to provide the best educational content to their students in collusion with their most prevalent donor partner countries such as Australia and New Zealand. Moreover, recent research has shown that in order to improve the quality and equity of university science teaching, it makes sense to utilise the culture of the students who are struggling in a system dominated by another worldview. This further emphasizes the benefits of embedding indigenous knowledge and values and the potential to make institutional change for the betterment of student academic achievement (Fonua, 2018). If there are issues of engagement, achievement and success for Tongan science learners which accounts for the decrease in scientific interest, these can be overcome by understanding and incorporating various Tongan cultural practices and approaches to education and learning can provides tangible solutions to these problems.

The historical lack of suitably qualified science teachers has most likely not benefitted Tongan students' attitude toward science. Less qualified and experienced teachers have a ripple-on effect on the poor quality of delivery in schools and universities, and can often result in low levels of achievement among their students (Throsby & Gannicott, 1990). Furthermore, the low wages associated with such positions exacerbate this problem, as they are unlikely to attract high-quality teachers with suitable qualifications. However, recent shift in the nation's priorities has seen more government resources invested into upgrading and upskilling science teachers, providing scholarships for students to take science programmes at a tertiary level, improvement of science laboratory facilities, and the creation of jobs in targeted areas in science. Some of the government's recent commitments to address these problems include its support of the Science Teachers Accelerated Programme (STAP) and Tonga In-country Science Programme (TISP). After the successful operation of STAP in Samoa, the Tongan government sent a strong message to the University of South Pacific to operationalise STAP and also design a face-to-face science programme for its freshmen, termed the TISP (Sharma et al., 2018a, 2019b).

The STAP was introduced to the USP Tonga Campus in 2017, where in partnership with the Asian Development Bank (ADB), scholarships were provided to a cohort of 45 science teachers and civil servants to upgrade their qualification to a Bachelor of Science. Both programmes completed their first round in 2019 with very high pass rates and student/stakeholder satisfaction.

Nevertheless, definitive data on student attitudes toward any aspect of education in Tonga is scarce, in part due to its relatively small population size. Previous researchers have investigated the attitude/perception of university and secondary students toward the use of Information and Communication Technology (ICT) learning resources in a number of countries but this has not been extended to the assessment of student attitudes toward science, particularly in secondary students (Johnson et al., 2021; Reddy et al., 2016, 2020b; Sharma & Reddy, 2015; Sharma et al., 2018b, 2019a, 2020). Thus, it is important to obtain baseline data on the attitudes of Tongan secondary students toward the study of science, in order to inform future education development policy of Tonga and the Pacific region. Data and research-driven STEM interventions in the education sector will play an arterial role in shaping the future development and economy of the PICs, as well as ensure preparedness for emergencies and crises such as COVID-19.

The Importance of Attitude Toward Science

The apparent reduction in people pursuing science-related careers (Broggy et al., 2017; Kirby & Cullinane, 2017) has been linked by several authors to a general decline of interest in science among secondary students (De Broucker et al., 2001; Dekkers & De Laeter, 2001). Students' attitude toward science has the potential to impact not only on their interest in pursuing science-related careers (Park et al., 2009), but also on their academic performance in science-related subjects. Germann (1988) found a moderate correlation between high school students' attitude toward science and their achievement in science-related subjects (as measured by the quality of work that the students produced). Similarly, Oliver and Simpson (1988) found a strong relationship between affective behaviours toward science in the classroom and student achievement. Furthermore, Barmby et al. (2008) found that attitude toward science amongst early secondary students impacted on their future participation in science subjects. Hence it is of considerable importance to understand the attitudes that students have toward science.

Most studies relating to attitude have considered used a tripartite model framework, whereby attitude is considered to encompass cognitive, affective and behavioural components (Eagly & Chaiken, 1993). However, van Aalderen-Smeets et al. (2012) found that this framework did not fit well for their study on primary science teachers, and proposed a modified theoretical framework consisting of "cognitive beliefs", "affective states" and "perceived control". This latter component includes the individuals' perceived self-efficacy, as well as their dependency on context factors (external factors which can assist or hinder the study of science). This echoed earlier work by Haladyna et al. (1982), who proposed a theoretical model of factors which may affect student attitude toward science, comprising non-controllable

factors (e.g. student gender, teacher age, classroom condition) and controllable factors (e.g. how the class is run, quality of student–teacher relationships, teaching styles, use of positive feedback). These authors noted that student fatalism and their perception of the importance of science were the major variables driving students' attitude toward science.

It is important to note that attitude is not fixed, and can be influenced through external influences including dedicated and knowledgeable teachers, or through meaningful learning strategies applied by the student (Brown et al., 2014b, 2015; Naiker et al., 2021). However, most longitudinal studies have found that during schooling years, the attitude of most students toward science slowly declines, or remains relatively constant in some instances (George, 2000; Gibson & Chase, 2002). Given the important influence that attitude toward science has on career interest in science and potentially academic achievement, we sought to investigate the attitude toward science among senior secondary Tongan students in this study.

In order to ensure that comparable data with high degree of reliability and consistency is attained, it is paramount that a standardised method of assessing scientific related attitudes should be utilised. There is no shortage of potential survey instruments to choose from, with a systematic review by Blalock et al. (2008) identifying 66 different published instruments for the assessment of attitudes toward science. However, the majority of these were reported by their designer in a single paper with no subsequent use by other researchers. Only 15 instruments were used in 3 or more studies (Blalock et al., 2008). Hence, a high quality, reliably validated survey instrument with a strong historical record is required. The Test of Science Related Attitudes (TOSRA) was first developed by Fraser (1978) in the 1970s. It scored second highest in the review of Blalock et al. (2008) in terms of its overall reliability, validity and theoretical background, second only to the Attitude Toward Science in School Assessment (ATSSA) instrument of Germann (1988). However, the ATSSA instrument has not been used by any subsequent researchers. Other survey instruments considered for this study included the Scientific Attitude Inventory (Moore & Sutman, 1970), the Image of Science and Scientists Scale (Smith & Krajkovich, 1979), and the Relevance of Science Education (ROSE) Questionnaire (Ogawa & Shimode, 2004). All of these instruments have been utilised in follow-up studies; however, all of the instruments have only undergone minimal reliability and validity testing. In contrast, several validation studies have been performed on TOSRA since its inception (Anwer et al., 2012; Khalili, 1987; Schibeci & McGaw, 1981; Stolarchuk & Fisher, 2001), enhancing the confidence of results obtained via this instrument. Hence we selected the TOSRA instrument in view of its previous validation, high ranking in the review of Blalock et al. (2008) and extensive use in the scientific literature. Dozens of studies have used TOSRA to date, making it one of the more popular instruments among contemporary researchers.

For example, Sangkala and Doorman (2019) used the TOSRA instrument to investigate the impact of influence of inquiry-based learning methods on Indonesian students' attitude toward science, finding that this teaching method did not have a significant impact on student attitudes. Similarly, (Desy et al., 2018) used TOSRA to demonstrate that student attitudes toward science improved throughout the course of an introductory biology unit, but the implementation of an online, inquiry-based

laboratory project had no significant effect on student attitudes. Toma et al. (2019) used an adaptation of the TOSRA instrument to investigate the attitudes toward science amongst elementary students from Spain. These researchers found that third graders had more positive attitudes toward science compared to fifth or sixth graders, highlighting that the observed decline in positive attitudes toward science are beginning at a very young age amongst school children. Finally, Naiker et al. (2020) conducted a survey of attitude toward science among Fijian students using the TOSRA instrument, finding comparable attitudes to previous work on Australian students. It was also noted that females began Year 11 with a more positive attitude toward science than males, but this had fallen by Year 13. This concurred with the results of a meta-analysis by Weinburgh (1995), which found that males tended to have more positive attitude toward science compared to females. However, Akpınar et al. (2009) reported contrasting results for Turkish students, with females having a higher interest in science than males. This indicates that gender differences in attitude toward science may vary significantly depending on the country.

To the best of our knowledge, no previous work has been performed on investigating the attitudes of Tongan secondary school students toward science. The first focus of this study was to answer the following descriptive research question:

- What are the attitudes towards the study of science amongst senior secondary Tongan students, based on their gender, form level and school location (urban vs rural)?

In addition, our investigation was guided by two related exploratory research questions:

- Does the attitude towards the study of science differ significantly amongst senior secondary Tongan students of different genders, form levels or school locations (urban vs rural)?
- Is there a significant interaction between gender, form level or school location in the attitude toward the study of science amongst senior secondary Tongan students?

Methods

The TOSRA Instrument

This study utilised the Test of Science Related Attitude (TOSRA) instrument, administered as described by Fraser (1981). The scale for this instrument is divided into seven attitude scales, namely Social Implications of Science (S), Normality of Scientists (N); Attitude to Science Inquiry (I); Adoption of Scientific Attitudes (A); Enjoyment of Science Lessons (E); Leisure Interest in Science (L); and Career Interest in Science (C) (Fraser, 1978).

Each scale contained 10 equally weighted items (statements) for a total of 70 items. Items were either positively worded or negatively worded. An example of a

positively worded item is "I would like to be a scientist when I leave school" (for scale C), while a negatively worded item was "Science lessons bore me" (for scale E). Within each item, five choices were possible: strongly agree, agree, not sure, disagree and strongly disagree. The answers for each item were ranked from 1 to 5, with a higher score indicating a more positive attitude toward science. Hence for positively worded items, a "strongly agree" response was scored as a 5, while for negatively worded items, a "strongly agree" response was ranked as a 1.

The scores for all 10 items were summed for each respondent to provide an overall score for each scale, ranging from 10 (poorest attitude toward science) to 50 (best attitude toward science), with a score of 30 being in the centre (i.e. "ambivalent" or uncertain). Invalid or absent responses were scored as 3, as recommended by Fraser (1981).

In addition, each respondent was asked to nominate their school's name, form level, gender (male or female), ethnic identity (Tongan or Other) and their first language (Tongan, English or Other). The school name was subsequently used to classify students as being from either an urban or rural area (as described in "Instrument Administration" section). As the vast majority of all respondents reported both their ethnicity as Tongan (95.3%) and first language as Tongan (90.6%), these parameters were not considered in subsequent statistical analyses.

Instrument Administration

Approval to conduct this study in Tongan secondary schools was obtained from the University of the South Pacific Research Office (Reference number: URC Funding/2016) and the Ministry of Education Tonga (Reference number: ORG 1/8v15). All data were collected anonymously. Students were able to decline participation or withdraw at any point of the study prior to collection of their responses.

As all Tongan schools provide at least part of their education in English, the use of an English version of the TOSRA instrument was considered appropriate for this study. However, it would be of interest for future work to assess potential differences comparing a translated version of the TOSRA instrument to results obtained using the English version, specifically amongst Pacific Island students.

The study population comprised twenty-six (26) secondary schools across the four major regions of Tonga:'Eua, Ha'apai, Tongatapu and Vava'u. Twenty (20) of the schools were classified as being in an urban region (in the direct vicinity of the capital, Nuku'alofa), while the remaining six (6) were classified as rural. Within each school, all students in forms 5, 6 and 7 (corresponding approximately to grades 11, 12 and 13, or 15–18 years of age) were invited to participate. Hardcopy versions of TOSRA were administered during the 2017 school year with the assistance of the Tongan Ministry of Education and Training. The total sample size of the respondents comprised of 2636 students (38.8% males and 60.2% females). Of these, 1431 students were in form 5, 833 in form 6 and 372 in form 7.

Statistical Analysis

The instrument validation methods used in this study followed that of Khalili (1987). In order to provide an estimate of the reliability of the results, the Cronbach α coefficient was calculated, as used in previous studies (Cronbach, 1951; Fraser, 1978; Naiker et al., 2021). In addition, the index of discriminant validity was calculated as the mean correlation with the other scales (Khalili, 1987).

All statistical analysis was performed on the total of the respondent's overall score for each of the 7 scales (ranging from 10 to 50, as each scale comprised 10 items which were each numbered from 1 to 5). To perform the descriptive analysis, the mean and standard deviation were calculated for each form level, gender and school location (rural vs. urban). If the demographic data were incomplete for a student (e.g. gender), all responses from that student were excluded from analyses pertaining to that demographic parameter only.

To answer our exploratory research questions, a three-way ANOVA was performed on the mean score for each student (averaged across all seven scales), with gender, form level and school locality used as the independent variables. A three-way ANOVA was considered to be the simplest form of analysis to answer both exploratory research questions, given that the data met the assumptions of parametric testing. A p value of < 0.05 was considered to be statistically significant. The statistical analyses were performed in R Studio, running R 4.0.2 (R Core Team, 2020) and SPSS (v26).

Results and Discussion

Validation of the TOSRA Instrument

Although the focus of this study was not to re-validate the TOSRA instrument, we conducted several validity tests to ensure that the results obtained among the Tongan study population showed similar reliability and validity to those obtained among most westernized countries.

The internal consistency reliability (the extent to which items in a given scale measure the same attitude) was calculated for each TOSRA scale using the Cronbach α coefficient, as described by Cronbach (1951). This determines the level to which items within the same scale is measuring the same attitude. Values of 0.7 or above are generally considered indicative of acceptable reliability (Cortina, 1993), with higher values indicating that all items are measuring the same attitude to a high degree. The mean values of the reliability coefficient ranged from 0.81 to 0.86 (Table 1), comparable to the results of previous studies (Khalili, 1987; Schibeci & McGaw, 1981). A closer examination of the internal consistency, through dropping one scale at a time and recalculating the Cronbach α, suggested that removing any one scale would not significantly improve the reliability of the results (data not shown).

Similarly, the indices of discriminant validity ranged between 0.26 and 0.53 (Table 1), indicating that the scales were each measuring different aspects of student

Table 1 Validation statistics for the TOSRA instrument (n = 2636 students)

Scale	Index of internal consistency (cronbach α)	Index of discriminant validity (mean correlation with other scales)
S (social implications of science)	0.82	0.47
N (normality of scientists)	0.86	0.27
I (attitude toward scientific inquiry)	0.84	0.40
A (adoption of scientific attitudes)	0.83	0.41
E (enjoyment of science lessons)	0.81	0.53
L (leisure interest in science)	0.81	0.50
C (career interest in science)	0.81	0.52
Mean	0.83	0.44

attitudes toward science. This range of values was comparable to Khalili (1987), who reported index values between 0.22 and 0.65.

To determine whether factor analysis supported the classification of the TOSRA items into the seven scales, principal component factor analysis was performed using varimax rotation (Khalili, 1987). The dataset was sufficiently large to support this analysis, with a value of 0.950 found for the Kaiser–Meyer–Olkin measure of sampling adequacy and $P < 0.001$ for Bartlett's Test of Sphericity.

As previously observed by Khalili (1987), the seven-factor model did not fit the data well, therefore the varimax rotation was rerun with six factors. These six factors cumulatively explained 35.9% of the variability observed between items in the dataset. As noted in previous validation studies (Khalili, 1987; Schibeci & McGaw, 1981), most of the items loaded onto the first three to four factors.

In most instances, the items from one TOSRA scale loaded onto two different factors, indicating a lack of operational similarity in the student responses (Table 2). This was most notable for scale N (normality of scientists), where the items were spread across three different factors. Normality of scientists can be described as the manifestation of favourable attitudes toward scientists (Fraser, 1981), or perceiving scientists as people who look ordinary but can think scientifically and solve science-related problems (Astalini et al., 2020). Overall, these results concurred with Schibeci and McGaw (1981), who demonstrated that the factor structure of the TOSRA instrument was not evident in students' response patterns, but it was supported by the conceptual framework of teachers. To ensure that the data collected here are easily comparable to previous studies, we present the data in terms of the seven original TOSRA scales throughout the rest of the paper. However, we do note that future studies should further investigate how best to combine the items of the TOSRA instrument into conceptually and operationally distinct groups.

Descriptive Analysis of Attitudes by Gender, Form Level and School Locality

In order to describe the attitudes towards the study of science amongst senior secondary Tongan students, based on their gender, form level and school location

Table 2 Factor analysis of TOSRA instrument (varimax rotated matrix) for 6 factors (n = 2636 students)

Scale	Item	Factor1	Factor2	Factor3	Factor4	Factor5	Factor6
S	Q64	0.51			0.31		
S	Q8	0.39					
S	Q22	0.35			0.28		
S	Q43		0.46	0.29			0.36
S	Q29		0.40	0.25			
S	Q57		0.36	0.35			0.41
S	Q15		0.28	0.26			
S	Q1			0.31			
S	Q50				0.33		
S	Q36					0.28	
N	Q37		0.29	0.28			
N	Q23		0.27				
N	Q51		0.25				
N	Q58					0.38	
N	Q16					0.46	
N	Q2					0.42	
N	Q30				0.25		
N	Q44				0.32		
N	Q9						
N	Q65						
I	Q59		0.29	0.32			
I	Q45		0.27	0.35			
I	Q17		0.26	0.43			
I	Q3			0.40			
I	Q24				0.44		
I	Q10				0.32		
I	Q52				0.48		
I	Q66				0.44		
I	Q38				0.35		
I	Q31						
A	Q39	0.40			0.40		
A	Q11	0.40					
A	Q25	0.38			0.36		
A	Q67	0.34			0.30		
A	Q46		0.33	0.39			
A	Q60			0.27			
A	Q32			0.36			
A	Q18			0.46			
A	Q4			0.31			
A	Q53				0.30		
E	Q26	0.72					
E	Q12	0.71					

Table 2 (continued)

Scale	Item	Factor1	Factor2	Factor3	Factor4	Factor5	Factor6
E	Q68	0.63					
E	Q40	0.63					
E	Q54	0.49			0.33		
E	Q47		0.76				
E	Q61		0.72				
E	Q33		0.54				
E	Q19		0.53				
E	Q5		0.44				
L	Q41	0.65					
L	Q27	0.61					
L	Q69	0.60					
L	Q13	0.60					
L	Q55	0.51					
L	Q48		0.72				
L	Q6		0.65				
L	Q20		0.61				
L	Q34		0.59				
L	Q62		0.53				
C	Q49	0.65					
C	Q35	0.62					
C	Q21	0.60					
C	Q7	0.55					
C	Q63	0.54					
C	Q70		0.72				
C	Q42		0.69				
C	Q14		0.57				
C	Q56		0.53				
C	Q28		0.43	0.30			

Values less than 0.25 were suppressed

Table 3 The mean scores with their standard deviation for each scale of the TOSRA instrument at different form levels

Scale	Form 5 (n = 1431)	Form 6 (n = 833)	Form 7 (n = 372)
S (social implications of science)	33.0 ± 4.7	32.8 ± 4.6	32.9 ± 4.3
N (normality of scientists)	31.4 ± 4.5	31.8 ± 4.4	32.3 ± 4.1
I (attitude toward scientific inquiry)	32.3 ± 5.2	32.6 ± 5.0	32.3 ± 4.5
A (adoption of scientific attitudes)	32.3 ± 5.1	31.8 ± 4.9	31.6 ± 4.6
E (enjoyment of science lessons)	32.3 ± 6.6	31.6 ± 6.3	31.0 ± 5.9
L (leisure interest in science)	31.8 ± 6.5	31.4 ± 6.3	31.3 ± 5.9
C (career interest in science)	32.2 ± 6.2	31.6 ± 5.9	31.2 ± 5.5
Mean	32.2 ± 4.1	31.9 ± 3.9	31.8 ± 3.6

Table 4 The attitude of male and female Tongan secondary students toward science

Scale	Male (n=606)	Female (n=810)
S (social implications of science)	32.7±4.9	33.2±4.6
N (normality of scientists)	31.4±4.8	31.5±4.3
I (attitude toward scientific inquiry)	32.0±5.3	32.6±5.1
A (adoption of scientific attitudes)	31.6±4.9	32.8±5.2
E (enjoyment of science lessons)	31.9±5.9	32.6±7.0
L (leisure interest in science)	31.8±6.1	31.8±6.8
C (career interest in science)	32.0±5.8	32.4±6.6
Mean	31.9±4.0	32.4±4.2

Results are the mean score for each scale with its standard deviation

Table 5 The attitude toward science of Tongan secondary students from urban and rural school locations

Scale	Rural (n=990)	Urban (n=1646)
S (social implications of science)	33.0±4.7	32.8±4.6
N (normality of scientists)	31.3±4.4	31.9±4.5
I (attitude toward scientific inquiry)	32.2±5.3	32.5±4.8
A (adoption of scientific attitudes)	32.7±5.3	31.7±4.8
E (enjoyment of science lessons)	32.1±7.0	31.8±6.0
L (leisure interest in science)	31.4±6.8	31.7±6.1
C (career interest in science)	31.9±6.4	31.9±5.9
Mean	32.1±4.2	32.0±3.8

Results are the mean score for each scale with its standard deviation

(urban vs rural), the mean and standard deviation were calculated for each scale of the TOSRA instrument for each of these groups.

As indicated in Table 3, the attitudes toward science were fairly consistent across the three form levels (form 5, 6 and 7), although the mean scores did appear to fall slightly for certain scales (e.g. A, E, L, C). In general, scales N (normality of scientists) and L (leisure interest in science) showed the lowest mean scores, indicating that students were less likely to have a strong leisure interest in science, or to view scientists as everyday people. In contrast, the highest values were found for scale S (social implications of science) across all three forms, indicating that Tongan students appear to have a good concept of the importance of science to society and their lives.

There were minor differences in the attitude towards science amongst male and female students (Table 4), with females scoring somewhat higher on scales A (adoption of scientific attitudes) and E (enjoyment of science lessons). However, the overall results are quite encouraging as they indicate relatively small gender differences in the attitudes of Tongan students toward science. This contrasted with the results of a meta-analysis by Weinburgh (1995), which found that across 18 previous studies, males generally had a more positive attitude toward science

compared to females. However, certain other studies have also reported females having a higher "interest in science" (Akpınar et al., 2009).

In a similar fashion, the attitude toward science was quite comparable between students from urban and rural school localities (Table 5), although students from rural areas did score higher on scale A (adoption of scientific attitudes). In contrast, urban students displayed a higher score for the normality of scientists (scale N). The difference in the former scale may be due to increased exposure of urban students to 'real-life' scientists, resulting in their slightly increased perception of scientists as 'normal' people. The reason for the difference in the latter scale remains unclear, although Astalini et al. (2020) also found slightly higher attitudes toward science amongst students from rural areas compared to those from urban areas. The authors suggested that students who live in rural areas could be involved in more hands-on experimental-type activities in their daily lives, leading to increased adoption of scientific attitudes and concepts such as inquiry-driven investigations. Our findings underscore the fact that learning and teaching science can be effective in any school if there are dedicated, genuine, high-quality staff and adequate learning resources available.

Overall, the range of mean scores found amongst Tongan students (31.0–33.0) was somewhat lower than that reported previously for Fijian senior secondary students (30.0–37.4) (Naiker et al., 2020) and Year 10 Australian students (26.9–38.4) (Fraser, 1978). Additionally, the range of scores was also much smaller than that found in both other countries, indicative of lower variability in the responses, possibly due to a more homogenous study population in terms of their culture, ethnicity and language spoken. Compared to Australian students, the Tongan students appear to have a lesser interest in science overall, particularly for scales N (normality of scientists) and A (adoption of scientific attitudes). However, they did score considerably higher in scale C (career interest in science) and scale L (leisure interest in science), with approximately similar levels on scale E (enjoyment of science lessons). Similar results to this have been previously found in Fijian secondary students (Naiker et al., 2020), which may hint at a wider trends in the attitudes of Pacific Island Country secondary school students toward the study of science.

Exploratory Analysis of Attitudes by Gender, Form Level and School Locality

The three-way ANOVA performed on the mean TOSRA scores revealed a significant interaction between form × gender (P = 0.012), as well as between form × gender × locality (P = 0.001) (Table 6). In other words, the change in attitudes across the three form levels showed different trends for males and females, and these trends were also affected by school locality (i.e. whether the school in which a student was enrolled in was from either an urban or a rural region). Examination of the marginal mean interaction plots (Fig. 1) supported this conclusion, as the change in attitude between different form levels varied with both gender and locality. Hence the ANOVA was re-run separately as a two-way ANOVA for students that were from rural areas, and for those students from urban areas.

Table 6 Results of the three-way ANOVA on the mean TOSRA scores, with gender, form level and locality as independent variables

Source	Type III sum of squares	df	Mean square	F ratio	Prob > F
Locality	15.927	1	15.927	1.021	0.312
Gender	3.039	1	3.039	0.195	0.659
Form	66.133	2	33.067	2.120	0.120
Locality × gender	40.627	1	40.627	2.604	0.107
Locality × form	20.141	2	10.070	0.646	0.524
Gender × form	137.975	2	68.989	4.423	0.012
Locality × gender × form	219.811	2	109.905	7.046	0.001
Locality: rural Gender × form	284.894	2	142.447	9.132	P < 0.05
Locality: urban Gender × form	32.536	2	16.268	1.043	NS
Locality: rural Gender: male Form	81.973	2	40.986	2.627	NS
Locality: rural Gender: female Form	230.060	2	115.030	7.374	P < 0.05
Residual	40,541.160	2599	15.599		
Total	2,724,118.163	2611			
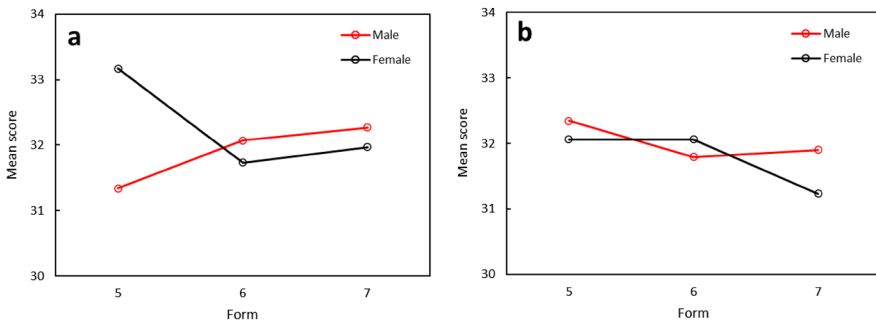
Fig. 1 The estimated mean scores for Tongan students across different form levels and genders, separated into **a** rural and **b** urban localities

The interaction between form × gender was found to be significant for students from rural localities ($F_{2,2599} = 9.13$, $P < 0.05$), but not for students from urban localities ($F_{2,2599} = 0.072$, $P > 0.05$), when using the per family error rate correction for 2599 degrees of freedom ($F > 3.69$) (Table 6). Similarly, further investigation of students only from rural localities revealed that the variance in attitude for different form levels was only significant for female students and not for male students (Table 6). This concurred with observations made from the three-way marginal

mean interaction plots (Fig. 1), where it can be seen that the attitudes of female students from rural schools toward science fell markedly from an average score of 33.2 in form 5, to an average score of 31.7 in form 6.

With respect to our original exploratory research questions, the following conclusions can be drawn:

- There is a significant interaction between school locality×gender×form level, and also between gender×form level for rural students.
- There is a significant change in the attitudes of female students at different form levels, but only if they are from rural areas. The change in attitude was not significant for female students from urban areas.
- There is no significant difference in the attitudes of male students from urban or rural school localities.
- Similarly, there is no significant change in the attitudes of male students at different form levels.
- There was no significant difference in the attitudes of male and female students, regardless of form level or locality.

It appears that female Tongan students in form 5 may have had a more positive engagement in their learning and teaching environment of science-related curricula, which subsequently seems to have receded in later forms. It is possible that this could be due to a lack of scaffolded engagement activities pertaining to science (such as hands-on experiments), which could result in the stagnation in their perception of science and loss of interest (Lombardi et al., 2018; Strati et al., 2017). A similar reduction in the interest of female students toward STEM fields has been reported during the high school years of students from the United States (Sadler et al., 2012), which was attributed to a possible failure to personally connect with young women's lives. Another study found an overall decline in the attitude toward science of English students between ages of 11 to 14, albeit to a higher degree in females (Barmby et al., 2008). However, it is important to note that a reduction in attitude was only observed for females from rural areas in the present study. Furthermore, the attitude of female students did not fall significantly below that observed for male students, but rather fell to a comparable level to that found for males in form 6 (Fig. 1).

Application to the Classroom and Beyond

Generally, it appears that the Tongan senior secondary students have a less positive attitude compared to students from Australian and Fiji, and as such, less interest in science overall. This difference is particularly prevalent for the adoption of scientific attitudes (scale A). Compared to previous data that has been collected on Fijian secondary students using the TOSRA instrument (Naiker et al., 2020), the mean score for all scales apart from N (Normality of Scientists) were lower in Tongan students. The most positive areas for Tongan students were scales E, C and L (enjoyment of science lessons, career interest in science and leisure interest in science), but the

mean score for these scales remained lower than Fijian students. Overall, the pattern of attitudes toward each scale were reminiscent of those found in Fijian secondary students which also reported higher enjoyment of science lessons but a lower score for the normality of scientists (Naiker et al., 2020). Most notably, there were no significant differences in the overall attitude towards science based on gender, form level or school locality; although there were significant interactions between several of these terms.

It is imperative that the stakeholders with a vested interest in the educational system understand and are open to advocacy for the potential implications of the findings reported here. Whilst this baseline research has unveiled a silver lining in that the most positive attitudes shown by Tongan senior secondary students are toward the enjoyment of science lessons and a career interest in science, the reality on the ground is that there is a general lack of interest towards science which needs to be addressed. The propounding key aspect is that science is a discipline that is best taught through scientific inquiry (Naiker & Wakeling, 2015; Rayner et al., 2013; Sangkala & Doorman, 2019). This will allow for considerable interest within the student to become motivated and engaged (such as in practical classes or a projects). In order to achieve this, educators need to be informed of contemporary methods of science delivery, continuous self-assessment of their practice(s) and being open to implementing subsequent modifications that may be required in the next offering of their class. However, the responsibility of providing qualified and trained science educators falls into the hands of the higher education providers—which for Tonga is primarily the regionally based university (USP) as well as the Tonga Institute of Higher Education (TIOE). Under the Tongan Ministry of Education and Training (MET), TIOE is the ultimate authority that provides training to those that choose to be primary or secondary school teachers. In recent years, USP has built a strong partnership with MET wherein USP offered relevant programmes in science at a degree level which secondary science teachers took part under local scholarship schemes. As part of USP's commitment to its regional member countries, these science programmes were offered at the USP Tonga Campus, giving the opportunity for the enrolled secondary teachers to complete their degree without surrendering their full-time teaching jobs or having to relocate to another country.

There is also the issue of the lack of localised scientific resources and relevant dynamic curriculum. As science educators are well aware, teaching science can be an expensive exercise due to the costly specialised laboratory resources needed, in addition to the technical skills expected of the teachers involved. Given the remoteness of the Tongan islands, virtual learning platforms and online teaching methods are likely to play an increasing role in equitizing education consumption for remote students (Reddy et al., 2020a; Sharma & Reddy, 2015), not just at a tertiary level, but also in the secondary education sector. Nevertheless, no amount of virtual learning can provide the practical skills learned through hands-on laboratory sessions. In this aspect, the USP Tonga Campus could potentially assist a limited number of secondary schools in the Tongatapu region by opening the campus laboratory facilities to these classes to use.

It is crucial that the USP plays a key role in liaising with the Tonga Ministry of Education and Training to initiate dialogues which will allow for the incorporation

of more engaging and scientifically inquired approach to teaching in secondary schools in Tonga. Through collaborative efforts, these stakeholders can have an influence in the modification of the education programs taught at USP to allow for teaching graduates to be better prepared with contemporary approaches to the scholarship of teaching and learning in secondary schools. If the USP shows leadership in being positive about improving the interest of secondary student in the PICs towards science, it can only be envisaged that represented governments of these countries would be more inclined to be open to suggestions towards curriculum and/or policy development.

With students' interest in science at an important juncture, the implications for PICs are very real if the attitudes of students are not improved with urgency. Commonly, PIC graduates seek greener pasture outside of their parent nation, especially in Australia, New Zealand, USA and Canada (Negin, 2008; Sikora & Saha, 2011). Whilst this "brain drain" results in a large void due to loss of trained and qualified graduates, it would have an even more significant impact in a sparsely populated country such as Tonga. Remarkably, the major source of income for Tonga is remittances from migrants (Brown, 1995; Gibson et al., 2019; Manu et al., 2016), which results in an extremely unstable economy (Fairbairn, 2019). Young educated high achievers have become one of the key pillars of support for their extended communal families in the islands, as they continually send money back from their overseas earnings (Gibson et al., 2019). In addition, Tonga has long been a huge beneficiary of aid and good will provided by neighbouring nations, such as Australian and New Zealand.

Going forward, Tonga, like all PICs, needs to become self-sufficient through their own investment policies for business, manufacturing, education and health, amongst other sectors. As these important aspects of the nation improve, job choices with higher earning potential will persuade many islanders to pursue their dreams in their own nations, rather than contributing to the ongoing "brain drain". In general, this will guide PICs like Tonga towards self-sufficiency and an even more highly knowledgeable, innovative and productive future in the South Pacific. Particularly at a time when the world is faced with a pandemic like COVID-19, the importance of science as an innovative, problem-solving discipline has never been more evident. From this aspect, educators and health care professionals have a major role to play. As such, it is more imperative than ever before that the developing PICs are assisted by Australia and New Zealand in the provision of more informed policy design focussed on the teaching of science and better equipping schools with appropriate resources and educators.

Conclusion

This work presented a comprehensive study of the attitudes of 2636 Tongan senior secondary students toward science, using the previously validated TOSRA instrument. The mean attitudes of these students toward science was lower across most aspects compared to that previously observed for Australian secondary students (Grades 7–10) and Fijian senior secondary students. However, within the study

population, similar trends were observed to those previously seen in Fijian students, with relatively higher attitudes toward the enjoyment of science lessons, leisure interest in science and career interest in science. The inter-correlation of these three scales (E, L and C) was supported by interrogation of principal component analysis loadings. Two-step cluster analysis indicated the presence of a distinct 'outlier' group of students, with a significantly higher attitude toward science across all scales. Notably, the attitude toward the normality of scientists did not appear to be correlated to any of the other scales, leading us to suggest that this aspect of students' perceptions and attitudes may be shaped primarily by social or cultural influences, rather than their individual perspectives toward science. Informed policy, ICT-driven learning and support strategies, well equipped science laboratories with requisite technology and curriculum design with a strong focus on teacher quality will be essential in the ongoing process of improving Tongan students' attitude and aptitude in scientific fields.

Data Availability The full dataset is available from the authors upon request.

Code Availability The code used for data analysis is available from the authors upon request.

Declarations

Conflict of interest The authors declare no conflicts of interest.

Ethical Approval Ethics approval for this study was obtained from University of the South Pacific Research Office (Reference: URC Funding/2016) and the Ministry of Education Tonga (Reference: ORG 1/8v15).

Informed Consent The study was explained to all participants or their parents/guardians and informed consent was obtained from all study participants prior to data collection. Students were able to decline participation or withdraw at any point of the study. Consent to publish collected data in an anonymised format was obtained from all participants included in the final dataset.

References

Akpınar, E., Yıldız, E., Tatar, N., & Ergin, Ö. (2009). Students' attitudes toward science and technology: An investigation of gender, grade level, and academic achievement. *Procedia - Social and Behavioral Sciences, 1*(1), 2804–2808. https://doi.org/10.1016/j.sbspro.2009.01.498

Anwer, M., Iqbal, H. M., & Harrison, C. (2012). Students' attitude towards science: A case of Pakistan. *Pakistan Journal of Social and Clinical Psychology, 9*(2), 3–9

Astalini, A., Kurniawan, D. A., Darmaji, D., & Anggraini, L. (2020). Comparison of students' attitudes in science subjects in urban and rural areas. *Journal of Educational Science and Technology (EST), 6*(2), 12057. https://doi.org/10.26858/est.v6i2.12057

Barmby, P., Kind, P. M., & Jones, K. (2008). Examining changing attitudes in secondary school science. *International Journal of Science Education, 30*(8), 1075–1093. https://doi.org/10.1080/0950069070 1344966

Blalock, C. L., Lichtenstein, M. J., Owen, S., Pruski, L., Marshall, C., & Toepperwein, M. (2008). In pursuit of validity: A comprehensive review of science attitude instruments 1935–2005. *International Journal of Science Education, 30*(7), 961–977. https://doi.org/10.1080/09500690701344578

Broggy, J., & O'Reilly, J., & Erduran, S. . (2017). 6. Interdisciplinarity and science education. In K. S. Taber & B. B. Akpan (Eds.), *Science Education: An International Course Companion.* (pp. 81–90). Brill.

Brown, R. P. C. (1995). Hidden foreign exchange flows: Estimating unofficial remittances to Tonga and Western Samoa. *Asian and Pacific Migration Journal, 4*(1), 35–54. https://doi.org/10.1177/01171 9689500400102

Brown, S., Sharma, B. N., Wakeling, L., Naiker, M., Chandra, S., Gopalan, R. D., et al. (2014a). Quantifying attitude to chemistry in students at the University of the South Pacific. *Chemistry Education Research and Practice, 15*(2), 184–191. https://doi.org/10.1039/c3rp00155e

Brown, S., Wakeling, L., Naiker, M., & White, S. (2014b). Approaches to study in undergraduate nursing students in regional Victoria, Australia. *International Journal of Nursing Education Scholarship, 11*(1), 155–164. https://doi.org/10.1515/ijnes-2014-0020

Brown, S., White, S., Wakeling, L., & Naiker, M. (2015). Approaches and study skills inventory for students (ASSIST) in an introductory course in chemistry. *Journal of University Teaching & Learning Practice, 12*(3), 6

Carpenter, V., & Taumoefolau, M. (2014). Ki He Lelei Taha: Talanoa Mei He Kaliloa of Successful Tongan Graduates. ResearchSpace@ Auckland.

Catherwood, V., Taufa, U., Scott, C., & Cook, B. (2003). *Final Report: Tonga—Education Sectors Study Report*. Government of Tonga.

Central Planning Department. (1991). *Sixth five-year development plan 1991–1995*. Kingdom of Tonga.

Charbannier, É., & Vayssettes, S. (2009). *PISA 2009 Presentation Note* (France). Organisation for Economic Cooperation and Development. Retrieved from http://www.oecd.org/pisa/46624019.pdf.

Cortina, J. M. (1993). What is coefficient alpha? An examination of theory and applications. *Journal of Applied Psychology, 78*(1), 98. https://doi.org/10.1037/0021-9010.78.1.98

Cronbach, L. J. (1951). Coefficient alpha and the internal structure of tests. *Psychometrika, 16*(3), 297–334. https://doi.org/10.1007/bf02310555

Dakuidreketi, M. R. (2014). Scientific method and advent of literacy: Towards understanding Itaukei and Indo-Fijian school students' differential achievement in science. *Universal Journal of Educational Research, 2*(2), 99–109

De Broucker, P., Bordt, M., Read, C., Harris, S., & Zhang, Y. (2001). Determinants of science and technology skills: Overview of the study. *Education Quarterly Review, 8*(1), 8

Dekkers, J., & De Laeter, J. (2001). Enrolment trends in school science education in Australia. *International Journal of Science Education, 23*(5), 487–500. https://doi.org/10.1080/09500690118451

Desy, E. A., Adams, C. T., Mourad, T., & Peterson, S. (2018). Effect of an online, inquiry- & mentor-based laboratory on science attitudes of students in a concurrent enrollment biology course: The PlantingScience experience. *The American Biology Teacher, 80*(8), 578–583. https://doi.org/10.1525/abt.2018.80.8.578

Eagly, A. H., & Chaiken, S. (1993). *The psychology of attitudes*. Harcourt Brace Jovanovich.

Fairbairn, T. I. (2019). The Tongan economy: recent performance and future challenges.

Farmer, S. S. (1855). *Tonga and the Friendly Islands: With a sketch of their mission history. Written for young people*. Hamilton, Adams, & co.

Fonua, S. (2018). Embedding indigenous science knowledge & values in higher education: Critical reflexive practice informed by Successful Tongan Science Learners. *Waikato Journal of Education, 23*(1), 95–106. https://doi.org/10.15663/wje.v23i1.629

Fraser, B. J. (1978). Development of a test of science-related attitudes. *Science Education, 62*(4), 509–515. https://doi.org/10.1002/sce.3730620411

Fraser, B. J. (1981). *Tosra: Test of science-related attitudes: Handbook*. Australian Council for Educational Research.

George, R. (2000). Measuring change in students' attitudes toward science over time: An application of latent variable growth modeling. *Journal of Science Education and Technology, 9*(3), 213–225. https://doi.org/10.1023/A:1009491500456

Germann, P. J. (1988). Development of the attitude toward science in school assessment and its use to investigate the relationship between science achievement and attitude toward science in school. *Journal of Research in Science Teaching, 25*(8), 689–703. https://doi.org/10.1002/tea.3660250807

Gibson, H. L., & Chase, C. (2002). Longitudinal impact of an inquiry-based science program on middle school students' attitudes toward science. *Science Education, 86*(5), 693–705. https://doi.org/10.1002/sce.10039

Gibson, J., McKenzie, D. J., & Rohorua, H. (2019). How cost elastic are remittances? Estimates from Tongan migrants in New Zealand.

Haladyna, T., Olsen, R., & Shaughnessy, J. (1982). Relations of student, teacher, and learning environmental variables to attitudes toward science. *Science Education, 66*(5), 671–687

Hazelkorn, E., Ryan, C., Beernaert, Y., Constantinou, C. P., Deca, L., & Grangeat, M., et al. (2015). Science education for responsible citizenship. *Report to the European Commission of the expert group on science education*. Brussels: European Comission EUR 26893 EN.

Johnson, J. B., Reddy, P., Chand, R., & Naiker, M. (2021). Attitudes and awareness of regional Pacific Island students towards e-learning. *International Journal of Educational Technology in Higher Education, 18*(1), 13. https://doi.org/10.1186/s41239-021-00248-z

Kennedy, J., Lyons, T., & Quinn, F. (2014). The continuing decline of science and mathematics enrolments in Australian high schools. *Teaching Science, 60*(2), 34

Khalili, K. Y. (1987). A crosscultural validation of a test of science related attitudes. *Journal of Research in Science Teaching, 24*(2), 127–136. https://doi.org/10.1002/tea.3660240205

Kirby, P., & Cullinane, C. (2017). Science shortfall. *The Sutton Trust: Research Brief, 17*, 1–8

Lombardi, D., Bailey, J. M., Bickel, E. S., & Burrell, S. (2018). Scaffolding scientific thinking: Students' evaluations and judgments during Earth science knowledge construction. *Contemporary Educational Psychology, 54*, 184–198. https://doi.org/10.1016/j.cedpsych.2018.06.008

Lotherington, H. (1998). Trends and tensions in post-colonial language education in the South Pacific. *International Journal of Bilingual Education and Bilingualism, 1*(1), 65–75

Manu, S., Taumoepeau, S., & Towner, N. (2016). Where do remittances go?: A Tongan case study. *CAUTHE 2016: The Changing Landscape of Tourism and Hospitality: The Impact of Emerging Markets and Emerging Destinations*, 1238.

Ministry of Education. (2000). *Guidelines for Tongan Language Programmes*. Learning Media Limited.

Ministry of Education. (2010). *Report of the Ministry of Education, women's affairs and culture for 2010*. Government of Tonga.

Moore, R. W., & Sutman, F. X. (1970). The development, field test and validation of an inventory of scientific attitudes. *Journal of Research in Science Teaching, 7*(2), 85–94. https://doi.org/10.1002/tea.3660070203

Naiker, M., Naidu, K., Johnson, J., Benveniste, T., Hill, D., & Wakeling, L., et al. (2021). Learning styles of undergraduate nursing students in Fiji—a Longitudinal Study. *Journal of University Teaching & Learning Practice*, submitted manuscript.

Naiker, M., Sharma, B., Wakeling, L., Johnson, J., Mani, J., Kumar, B., et al. (2020). Attitudes towards science among secondary students in Fiji. *Waikato Journal of Education, 25*(1), 57–72. https://doi.org/10.15663/wje.v25i0.704

Naiker, M., & Wakeling, L. (2015). Evaluation of group based inquiry oriented learning in undergraduate chemistry practicals. *International Journal of Innovation in Science and Mathematics Education, 23*(5), 1–17

Negin, J. (2008). Australia and New Zealand's contribution to Pacific Island health worker brain drain. *Australian and New Zealand Journal of Public Health, 32*(6), 507–511. https://doi.org/10.1111/j.1753-6405.2008.00300.x

Ogawa, M., & Shimode, S. (2004). Three distinctive groups among Japanese students in terms of their school science preference: From preliminary analysis of Japanese data of an international survey'the Relevance of Science Education'(ROSE). *Journal of Science Education in Japan, 28*(4), 279–291

Oliver, J. S., & Simpson, R. D. (1988). Influences of attitude toward science, achievement motivation, and science self concept on achievement in science: A longitudinal study. *Science Education, 72*(2), 143–155. https://doi.org/10.1002/sce.3730720204

Paongo, K. (1996). The nature of education in pre-European to modern Tonga. In P. Herda, J. Terrell, & N. Gunson (Eds.), *Tongan Culture and History.* (pp. 134–144). The Journal of Pacific History.

Park, H., Khan, S., & Petrina, S. (2009). ICT in Science Education: A quasi-experimental study of achievement, attitudes toward science, and career aspirations of Korean middle school students. *International Journal of Science Education, 31*(8), 993–1012. https://doi.org/10.1080/0950069070 1787891

Pasikale, A., Yaw, W., & Apa, K. (1998). *Weaving the way: Pacific Islands peoples' participation in the provision of learning pathways for Pacific Islands learners.* Pacific Islands Education Unit, Education & Training Support Agency.

Potvin, P., & Hasni, A. (2014). Analysis of the decline in interest towards school science and technology from grades 5 through 11. *Journal of Science Education and Technology, 23*(6), 784–802. https://doi.org/10.1007/s10956-014-9512-x

R Core Team. (2020). *R: A language and environment for statistical computing.* R Foundation for Statistical Computing.

Rayner, G., Charlton-Robb, K., Thompson, C., & Hughes, T. (2013). Interdisciplinary collaboration to integrate inquiry-oriented learning in undergraduate science practicals. *International Journal of Innovation in Science and Mathematics Education (formerly CAL-laborate International)*, 21(5).

Reddy, E., Reddy, P., Sharma, B., Reddy, K., & Khan, M. G. M. (2016), Student readiness and perception to the use of smart phones for higher education in the Pacific. In *2016 3rd Asia-Pacific World Congress on Computer Science and Engineering (APWC on CSE)*. 5–6 Dec. 2016. (pp. 258–264).

Reddy, E., Sharma, B., Reddy, P., & Dakuidreketi, M. (2017). Mobile learning readiness and ICT competency: A case study of senior secondary school students in the Pacific Islands. In *2017 4th Asia-Pacific World Congress on Computer Science and Engineering (APWC on CSE)*. 11–13 Dec. 2017. (pp. 137–143).

Reddy, P., Sharma, B., & Chandra, S. (2020a). Student readiness and perception of tablet learning in higher education in the pacific-a case study of Fiji and Tuvalu: Tablet learning at USP. *Journal of Cases on Information Technology (JCIT), 22*(2), 52–69. https://doi.org/10.4018/JCIT.2020040104

Reddy, P., Sharma, B., & Chaudhary, K. (2020b). Measuring the digital competency of freshmen at a higher education institute *PACIS*. 20–24 June. Dubai (pp. 1–13). Retrieved from https://aisel.aisnet.org/pacis2020/6.

Sadler, P. M., Sonnert, G., Hazari, Z., & Tai, R. (2012). Stability and volatility of STEM career interest in high school: A gender study. *Science Education, 96*(3), 411–427. https://doi.org/10.1002/sce.21007

Sangkala, N. R., & Doorman, L. M. (2019). The influence of inquiry-based learning on Indonesian students' attitude towards science. *Journal of Physics: Conference Series, 1321*, 032123. https://doi.org/10.1088/1742-6596/1321/3/032123

Schibeci, R. A., & McGaw, B. (1981). Empirical validation of the conceptual structure of a test of science-related attitudes. *Educational and Psychological Measurement, 41*(4), 1195–1201. https://doi.org/10.1177/001316448104100427

Sharma, B., Lauano, F. I. J., Narayan, S., Anzeg, A., Kumar, B., & Raj, J. (2018a). Science teachers accelerated programme model: A joint partnership in the Pacific region. *Asia-Pacific Journal of Teacher Education, 46*(1), 38–60. https://doi.org/10.1080/1359866X.2017.1359820

Sharma, B. N., Nand, R., Naseem, M., Reddy, E., Narayan, S. S., & Reddy, K. (2018b). Smart learning in the Pacific: Design of new pedagogical tools. In *2018 IEEE International Conference on Teaching, Assessment, and Learning for Engineering (TALE)*. 4–7 Dec. 2018. (pp. 573–580).

Sharma, B., Nand, R., Naseem, M., & Reddy, E. V. (2020). Effectiveness of online presence in a blended higher learning environment in the Pacific. *Studies in Higher Education, 45*(8), 1547–1565. https://doi.org/10.1080/03075079.2019.1602756

Sharma, B., Prasad, A., Narayan, S., Kumar, B., Singh, V., Nusair, S., et al. (2019a). Partnerships with governments to implement in-country science programmes in the South Pacific region. In *2019 IEEE Asia-Pacific Conference on Computer Science and Data Engineering (CSDE)*. 9–11 Dec. 2019. (pp. 1–6).

Sharma, B. N., Nand, R., Naseem, M., Reddy, E., Narayan, S. S., & Reddy, K. (2019b). Smart learning in the pacific: Design of new pedagogical tools. In *2018 IEEE International Conference on Teaching, Assessment, and Learning for Engineering (TALE)*. IEEE, (pp. 573–580).

Sharma, B., & Reddy, P. (2015). Effectiveness of tablet learning in online courses at University of the South Pacific. In *2nd Asia-Pacific World Congress on Computer Science and Engineering (APWC on CSE)*. 2–4 Dec. 2015. (pp. 1–9).

Sikora, J., & Saha, L. J. (2011). The concept of "talent loss" in educational theory and research. *Educational Practice and Theory, 33*(2), 5–22. https://doi.org/10.7459/ept/33.2.02

Sjøberg, S., & Schreiner, C. (2010). *The ROSE project: An overview and key findings*. (pp. 1–31). University of Oslo.

Smith, E. (2011). Staying in the science stream: Patterns of participation in A-level science subjects in the UK. *Educational Studies, 37*(1), 59–71. https://doi.org/10.1080/03055691003729161

Smith, J. K., & Krajkovich, J. G. (1979). Validation of the image of science and scientists scale. *Educational and Psychological Measurement, 39*(2), 495–498. https://doi.org/10.1177/001316447903900 233

Stolarchuk, E., & Fisher, D. (2001). An investigation of teacher-student interpersonal behavior in science classrooms using laptop computers. *Journal of Educational Computing Research, 24*(1), 41–55. https://doi.org/10.2190/hnb1-43eq-u7r3-2jqk

Strati, A. D., Schmidt, J. A., & Maier, K. S. (2017). Perceived challenge, teacher support, and teacher obstruction as predictors of student engagement. *Journal of Educational Psychology, 109*(1), 131–147. https://doi.org/10.1037/edu0000108

Thaman, K. H. (1988). *Ako and Faiako: Educational concepts, cultural values, and teacher role perception in Tonga*. University of the South Pacific.

Thaman, K. H. (1995). Concepts of learning, knowledge and wisdom in Tonga, and their relevance to modern education. *Prospects, 25*(4), 723–733

Thomas, R. M. (1984). Tonga. In R. M. Thomas & T. N. Postlethwaite (Eds.), *Schooling in the Pacific Islands: Colonies in transition.*Elsevier.

Thomas, R. M., & Postlethwaite, T. N. (1984). Country comparisons anf the future. In R. M. Thomas & T. N. Postlethwaite (Eds.), *Schooling in the Pacific Islands: Colonies in transition: Elsevier.*

Throsby, C., & Gannicott, K. (1990). The quality of education in the South Pacific. *Islands/Australia Working Paper-Australian National University, Research School of Pacific Studies, National Centre for Development Studies*, 90(9).

Toma, R. B., Greca, I. M., & Orozco Gómez, M. L. (2019). Attitudes towards science and views of nature of science among elementary school students in terms of gender, cultural background and grade level variables. *Research in Science & Technological Education, 37*(4), 492–515. https://doi.org/10.1080/02635143.2018.1561433

Trumper, R. (2006). Factors affecting junior high school students' interest in physics. *Journal of Science Education and Technology, 15*(1), 47–58. https://doi.org/10.1007/s10956-006-0355-6

Turner, S., & Ireson, G. (2010). Fifteen pupils' positive approach to primary school science: When does it decline? *Educational Studies, 36*(2), 119–141. https://doi.org/10.1080/03055690903148662

United Nations Economic and Social Commission for Asia and the Pacific. (2000). Review of Implementation of the Programme of Action for Sustainable Development of Small Island Developing States and the Regional Action Programme for Environmentally Sound and Sustainable Development. *Ministerial Conference on Environment and Development in Aisa and the Pacific—1996–2000: Pacific Perspective*. 31 Aug–5 Sep. Kitakyushu, Japan.

van Aalderen-Smeets, S. I., Walma van der Molen, J. H., & Asma, L. J. F. (2012). Primary teachers' attitudes toward science: A new theoretical framework. *Science Education, 96*(1), 158–182. https://doi.org/10.1002/sce.20467

Ware, H. (2007). Australia and education in the Pacific: What is relevant and who decides? *International Education Journal: Comparative Perspectives, 8*(3), 19–34

Weinburgh, M. (1995). Gender differences in student attitudes toward science: A meta-analysis of the literature from 1970 to 1991. *Journal of Research in Science Teaching, 32*(4), 387–398. https://doi.org/10.1002/tea.3660320407

World Bank. (2020). Tonga. Retrieved 1 March, 2021, from https://data.worldbank.org/country/tonga.