School Based Research Project

Final Report

Wenona School

Leading the Way
Girls and STEM

School: Wenona

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Executive Summary

The purpose of this research was to assess the impact of a combined Science, Technology, Engineering, and Mathematics (STEM) curricular and co-curricular program on girls' participation, attitude towards, as well as engagement and achievement in STEM related areas of education. This research was designed to be multifaceted in approach, with multiple intervention strategies encompassing both curricular and co- curricular areas of learning.

In order to study the impact of this program, girls at Wenona School in Years 7-12 were measured in terms of their attitude towards STEM subject areas. In addition, the participation rates of Higher School Certificate (HSC) students from the same school were tracked over a four-year period. This data was then compared to the participation rates of HSC students in NSW, where it was found that student participation still follows a stereotypical path in Mathematics, Science, and Technology and Applied Studies (TAS) subjects. A professional learning model was also implemented in order move the focus of the teaching and learning of mathematics and science to an inquiry based model. This involved working with Year 5-8 teachers on approaches to science and mathematics teaching that engaged students in quality learning in order to prepare them as problem solvers and inquirers for future STEM studies, and futures generally.

In science, this involved the use of a representation construction guided inquiry approach to support reasoning and deeper learning. In mathematics, this involved a problem solving approach that promoted spontaneous exploratory group activity that enabled all girls to contribute in various ways to the development of deep mathematical understandings, and build resilience through the successes they achieve, thus increasing their problem solving capacity over time. The focus in each case was on student engagement with inquiry and problem solving. The impact of these intervention strategies was then measured through a change in girls' attitudes and girls' decision to take up STEM subjects in Stage 6 as described above.

It is hoped that this research project can offer solutions to improve the educational outcomes for girls in all areas of STEM, not just at Wenona School but also more broadly. There is a significant gender disparity with regard to tertiary education and employment in these fields; however, to address these issues, it is firstly important to look at the primary and secondary educational setting in order to assess if specific strategies can change girls' perception of and skills in STEM fields, thus facilitating more girls into these areas in their post-school lives.

Introduction

The importance of this research project lies in addressing areas of local, national, and global concern regarding the participation of women in STEM related areas of industry and thus employment. This issue is important as STEM related areas, especially with regard to fields such as computer programming and coding, not only have immense gender disparity, they also represent areas of the greatest expected employment growth and subsequent remuneration. A lack of deliberate action for women in these fields threatens to make them bystanders in areas of economic growth and participation, thus exacerbating current issues of gender inequity. The aim of this research is to increase girls' participation, interest, engagement and ultimately performance in areas of STEM education and as a consequence, influence the transition of girls into post-school options of study and employment in these fields. In order to gain an understanding of these concerns a review of the literature will take place followed by a presentation and discussion of findings.

Literature Review

The Educational Context

The reform to Australian education that began in the 1970s had the intention of improving educational outcomes for girls in relation to the breaking down of gender stereotypes with regard to subject choices, thus making greater career options available to female students in their post-school lives (Kenway, 1990; Foster, 1992; Yates, 1993). However, nearly fifty years on, these reforms have not translated to the greater participation of girls in what are deemed 'traditional' male subject areas of study, such as the hard sciences, in particular physics, the more challenging mathematics courses, and subjects concerning computing, engineering and the use of hard materials (Cann, 2009). The impact of this lower participation, in comparison to males, has resulted in women not gaining access to STEM areas of employment (Sarkar, Tytler & Palmer, 2014), subsequently impacting on their attainment of leadership roles (EOWA, 2012) and the higher remuneration associated with these fields (WGEA, 2016).

In understanding these ideas, it is important to recognise the role that gender stereotypes play in relation to girls' participation and performance in STEM curriculum areas and future career aspirations. An understanding of gender and the prescriptions that are then assigned to gender, known as stereotypes, have a significant impact on how girls are perceived and the roles that they then perform (Archard, 2013). Gender stereotypes play a major role in the participation and success of girls in non-traditional curriculum areas such as those associated with STEM. The girls' school context offers the perfect opportunity to influence girls' participation in areas where they may otherwise revert to gender stereotype and avoid participation (Sax, 2006). Much research has further explored this debate. With regard to participation and success in what has been termed, 'non-traditional' female subjects, the following has been concluded. Girls in single- sex schools are more likely to undertake the study of higher level mathematics and science, and achieve better academically in these areas (Jones, 1995; McEwen, Knipe, & Gallagher, 1997; Van-de-gaer, Pustjens, Van-Damme, & DeMuster, 2004). Girls from single-sex schools are also reported to demonstrate higher levels of self-confidence and self-efficacy than girls from co-educational environments (Lloyd, Walsh, & Yailagh, 2005). As a result, girls' educational participation rates have increased, as has their entry into higher education. However, it has been noted that this increased academic success has not translated into life achievement for girls and that societal participation rates of women in traditionally non-female fields, including many areas of STEM, has remained low (Baker, 2010; Moyle & Gill, 2005; Skelton, 2010; Sarkar, Tytler & Palmer, 2014).

Girls and Academic Participation and Achievement

Girls' academic participation and performance in STEM related areas of education may be influenced by the attitudes and levels of confidence that they assign to STEM subject areas. Performance attribution is often linked to concepts such as confidence (Archard, 2012) and girls' confidence in their ability to perform and complete academic tasks may be related to their attitudes; particularly in the areas of subject enjoyment and perceived relevance. Performance attribution refers to the inferences that an individual makes about the causes of their successes and failures, this in turn effects a student's confidence to perform tasks (Lloyd, Walsh, & Yailagh, 2005).

The importance of these concepts lies in their association with learning and educational outcomes, particularly in relation to mindsets (Dweck, 2006). The perception that a child has of their own ability and their perceived attitudes towards academic subjects is an important signifier of their achievement related behaviour (Eccles & Wigfield, 2002). In an exploration of girls and confidence, some theorists have found that girls may find difficulty when confronted with experiences that are outside of their expected gender domain (Archard, 2012). This has been particularly linked to girls' lack of confidence and as a consequence, girls' underrepresentation and lower performance in subjects such as mathematics (Cann, 2009) and the sciences (Ziegler & Heller, 2000). This phenomenon is interesting when considering girls' increased levels of academic achievement in STEM areas of education yet lack of translation of this success into post-school education and career options.

The Teaching of Mathematics and Science in Schools

Reviewing how mathematics and science are taught at school can be one method to increasing students' enjoyment, confidence, and achievement in these subject areas, particularly in relation to girls. Methods that focus on inquiry learning where the students become constructors of knowledge rather than mere recipients of knowledge can make learning more relevant and meaningful to the student. The guided inquiry approach to teaching and learning called 'representation construction' is one such method (Tytler et al. 2013). Guided inquiry is loosely defined as an intermediate teaching method fitting between open-ended, student-directed learning and traditional, direct instruction (Furtak 2006). This teaching style encourages students to explore ideas and hypotheses, therefore fostering critical and scientific thinking whilst maintaining a level of direction from the teacher. Guided inquiry has been argued to be more effective and more efficient than open inquiry to teach students new concepts (Kirschner et al. 2006). This method can develop conceptual understanding and reasoning capacities as well as enable students to participate in knowledge production methods aligned with scientific and mathematical practice.

The development of optimism building through learning tasks that develop 'big ideas' (Williams, 2013) is another effective method for developing student learning in mathematics and pedagogical practice in teachers. Williams' research describes an optimistic student as one who sees not knowing as temporary and able to be overcome through personal effort, looks into situations to find what can be changed, understands that external factors may not change, and sees success as pervasive or due to a characteristic of self: "I succeeded; I am good at this". Overall, students display persistence in the face of adversity. By reassessing the way that we teach girls, and in particular using methods that focus on inquiry and confidence building, we can hope to engage girls in the learning of mathematics, science, and other STEM related fields such as engineering, and through their participation and success in these curriculum areas, encourage them into STEM careers into the future.

Research Aim

The aim of this research was to understand girls' participation, attitude towards, and engagement in STEM related areas of education at Wenona School. In order to do this, the following took place:

1. Review of the literature with regard to girls and STEM.
2. Quantitative review of trend data in relation to the gender distribution of NSW Higher School Certificate STEM related subjects.

3. Implementation and study of a professional learning approach to the teaching of science and mathematics aimed at engaging students in quality learning in order to prepare them as problem solvers and inquirers in future STEM studies.
4. Study of the impact of an implemented curricular and co-curricular initiatives/program in relation to girls' attitudes towards and participation in STEM subject area.

Research Questions

The aim of this study was to explore the following research question:

- Does the implementation of a specific STEM program at Wenona School influence girls' attitudes towards as well as engagement and participation in STEM related curriculum areas?

In order to address this research question, the following questions of enquiry were explored.

1. What has been the trend in relation to the gender distribution of HSC STEM curriculum subjects over the last four years?
2. What has been the trend at Wenona School over the last four years concerning subject selection in STEM curriculum areas?
3. What impact does the implementation of a specific approach to the teaching of mathematics and science in Years 5 to 8 have on teacher and student understanding of inquiry learning?
4. What attitudes do students at Wenona School have in relation to STEM subject areas of education?

Methods and Data Collection

In answering the questions above, this study used both qualitative and quantitative methods of data collection and analysis in order to gain a broader understanding of the concepts under investigation. As stated by Patton (2002):

> Multiple sources of information are sought and used because no singular source of information can be trusted to provide a comprehensive perspective…each type and source of data has strengths and weaknesses. Using a combination of data types…increases validity as the strengths of one approach can compensate for the weaknesses of another approach. (p. 306).

This process, known as overlapping methods, ensures that the different methods of data collection all point to the same conclusion. As a result of this process triangulation can occur, thus giving validity to the research findings. Thus, in order to answer the research questions, the following methods of data collection were implemented:

- A quantitative analysis of participation rates by gender in NSW Higher School Certificate STEM subjects as well as participation rates at Wenona School in Mathematics and Science Higher School Certificate subject areas.
- Longitudinal survey of students at Wenona School in Years 7 to 12, conducted by the Australian Science Enrolment Project, measuring attitudes towards STEM related curriculum areas.
- A professional learning approach using workshops, video analysis of lessons, teacher and student interviews and focus groups and artefact analysis conducted by Deakin University.

Quantitative Trend Analysis

Data was collected from the Board of Studies Teaching and Educational Standards (BOSTES) NSW website. This data is publically available and presents statistics concerning HSC student entries by sex for each HSC course for every calendar year. Data was also collected from Wenona School's HSC Results List in order to ascertain participation rates in HSC Mathematics and Science courses. In both cases data were collected for the last four years: 2012 to 2015.

Longitudinal Survey

An online attitudinal survey was administered to all students in Years 7 to 12 at two points during the school calendar year, these being Term 2 and Term 4. This survey was part of a separate research study being conducted by the Australian Science Enrolment Project by Mr John Kennedy. The survey instrument consisted of 68 items and was used to identify the attitudes of students in relation to seven domains:

- Ability
- Enjoyability
- Usefulness (specific)
- Usefulness (career)
- Difficulty
- Relevance
- Intentions

It is the school's intention to collect and analyse trend data in relation to student attitudes beyond the period of this research project.

Professional Learning Approach for Years 5-8 Mathematics and Science Teachers

This phase of the project included working with teachers to develop teaching programs and assessments under an inquiry model of teaching and learning, as well as the study of pedagogical practice and the review of student learning outcomes. The initiative began with an initial meeting for Science and Mathematics teachers to describe the research approach and the pedagogies. This was followed by a series of separate 2-hour workshops for the Year 5 to 8 Science and Mathematics teachers, introducing the approach and planning tasks. In both mathematics and science there were 4 workshops between July and November 2015 and a further 4 workshops between March and August 2016. Each workshop involved the following cycles in which:

1. The research team planned activities with teachers that exemplified pedagogical approaches that built student engagement with reasoning and the nature of successful problem solving strategies.
2. Teachers trialled these approaches in year level teams, capturing key aspects on video for subsequent discussion. The process involved:
    - an initial session with teachers as they familiarised themselves with the task, how they might implement it, and what students might do;
    - one teacher implemented the task in their class and other teachers observed student responses and considered what they might do if such a response arose in their class;
    - a teacher debrief session that focused on what worked well, and what teachers might want to think further about;
    - teachers trialled and videoed task implementation in their class between professional learning blocks with similar debriefings undertaken by staff between trials; and
    - teachers brought self-selected video excerpts to discuss at workshop sessions.
3. During the series of workshop visits the research team reviewed with teachers their experience and ideas, based on reporting of teacher experience, student learning supported by artefacts such as reports and scanned drawings and models, and video stimulated discussions.
4. This then led to further planning cycles.

Monitoring Instruments

Change in teacher behaviour has been monitored using:

- A component mapping instrument which involved an interview protocol on teacher practice, administered at the start of the project and a year later. This involved a 20-minute interview for each teacher in which they discussed and mapped their practice across a number of components.

- Video stimulated discussions, and teacher interviews, tracking changes in teacher practice and teacher language around student engagement with learning.
    - Analysis of planning meeting discussions

Student outcomes were tracked through:

- Science: a pre and post-tests of conceptual outcomes, pre and post interviews with groups of students (selected for diversity of engagement, and performance) to identify their engagement with reasoning and meta representational competence.
- Mathematics: teacher observations of students as they progressively undertook problem solving tasks to see whether there were changes in the ways they approach mathematics. Individual interviews with students from each level for whom changes have occurred, for the purpose of capturing what has brought about the change.
- Student produced artefacts in both subject areas

Teacher Video Based Reflection

The Deakin team has developed a video capture system with go-pro cameras, one with a swivel-mount tracking device and radio microphone on the teacher, and another sitting unobtrusively capturing video of a group of students for team reflective discussions. These were in some cases mounted on the Wenona shared video platform for analysis prior to meetings, and in other cases viewed at the review workshops as the basis for reflective discussion. A number of teachers, particularly in the primary school, and for mathematics in the secondary school, used iPads instead of cameras, and brought these to the sessions for showing and discussion. These small team video based discussions were intended to form a significant part of the professional learning approach.

Participants

Participants of this study were all students and teachers at Wenona School. Wenona School is a K-12 Independent girls' school located in North Sydney, Australia. The school is academically non-selective and caters for a range of student abilities. Students who participated in interviews and focus groups were purposefully selected based on their capacity to undertake an interview/focus group process, academic ability was not a selection criterion. All students in Years 7-12 participated in the online attitudinal survey. Teacher participants were purposefully selected based on their teaching allocation as a classroom teacher of Year 5 and 6, or a Mathematics and Science teacher of Years 7 and 8.

Results and Findings

The aim of this research project was to address the underrepresentation of girls in STEM related curriculum subjects through a study of an implemented co-curricular and curricular STEM program at Wenona School. Before presenting the findings of a pedagogical and professional development intervention, it is firstly important to review the trend data in relation to gender participation rates in NSW and the participation rates of Wenona students studying Mathematics and Science over the last four years.

Gender Distribution of HSC STEM Subjects

The following tables present the participation rates by gender in various STEM related subject areas in the NSW Higher School Certificate over the last four years.

Mathematics Courses

2015 HSC	Mathematics General 2		Mathematics		Mathematics Ext 1		Mathematics Ext 2	
Boys	15,795	50%	8,914	54%	5,233	58%	2,124	64%
Girls	15,719	50%	7,537	46%	3,722	42%	1,210	36%
Total	31,514	100%	16,451	100%	8,955	100%	3,334	100%

2014 HSC	Mathematics General 2		Mathematics		Mathematics Ext 1		Mathematics Ext 2	
Boys	15,785	49%	9,209	54%	5,522	60%	2,191	64%
Girls	16,286	51%	7,735	46%	3,692	40%	1,217	36%
Total	32,071	100%	16,944	100%	9,214	100%	3,408	100%

2013 HSC	General Mathematics		Mathematics		Mathematics Ext 1		Mathematics Ext 2	
Boys	15,881	49%	8,953	54%	5,191	59%	2,030	63%
Girls	16,498	51%	7,510	46%	3 ,648	41%	1,168	37%
Total	32,379	100%	16,463	100%	8,839	100%	3,198	100%

2012 HSC	Mathematics General 2		Mathematics		Mathematics Ext 1		Mathematics Ext 2	
Boys	15,804	50%	9,022	54%	5,247	59%	2,181	63%
Girls	15,898	50%	7,678	46%	3,678	41%	1,273	37%
Total	31,702	100%	16,700	100%	8,925	100%	3,454	100%

The tables above indicate the following:

- The hardest mathematics course, Mathematics Extension 2, has the greatest discrepancy between male and female participation, with the higher participation being male.
- The easiest mathematics course, Mathematics General 2, has an almost equal distribution between male and female participants.
- There has been little change (i.e. no more than 1%) to male and female participation rates across all mathematics courses between 2012 and 2015.

Sciences Courses

2015 HSC	Biology		Chemistry		Earth & Environmental		Physics		Senior Science	
Boys	6,701	39%	6,012	55%	874	60%	7,408	78%	3,456	55%
Girls	10,570	61%	4,895	45%	594	40%	2,103	22%	2,864	45%
Total	17,271	100%	10,907	100%	1,468	100%	9,511	100%	6,320	100%

2014 HSC	Biology		Chemistry		Earth & Environmental		Physics		Senior Science	
Boys	6,770	39%	6,250	55%	845	55%	7,669	79%	3,469	54%
Girls	10,627	61%	5,055	45%	680	45%	2,070	21%	3,004	46%
Total	17,397	100%	11,305	100%	1,525	100%	9,739	100%	6,473	100%

2013 HSC	Biology		Chemistry		Earth & Environmental		Physics		Senior Science	
Boys	6,539	39%	6,025	55%	703	50%	7,435	78%	2,908	53%
Girls	10,313	61%	5,007	45%	696	50%	2,127	22%	2,533	47%
Total	16,852	100%	11,032	100%	1,399	100%	9,562	100%	5,441	100%

2012 HSC	Biology		Chemistry		Earth & Environmental		Physics		Senior Science	
Boys	6,411	39%	5,989	55%	808	54%	7,349	78%	2,901	55%
Girls	10,159	61%	4,849	45%	689	46%	2,120	22%	2,334	45%
Total	16,570	100%	10,838	100%	1,497	100%	9,469	100%	5,235	100%

The tables above indicate the following:

- Physics has the greatest discrepancy between male and female participation, with boys having the higher participation rate of 78%.
- Chemistry has a 10% higher male participation rate than female.
- The gap between male and female participation in Earth and Environmental Science has doubled from 10% to 20%, with males having the higher level of participation.
- Female participation in Biology has consistently been 22% higher than male participation from 2012 to 2015.

Technology and Applied Science (TAS) Courses

2015 HSC	Design & Technology		Engineering Studies		Industrial Technology		Software Design & Development		Textiles and Design	
Boys	1,875	60%	1,950	95%	4,851	88%	1,688	95%	22	1%
Girls	1,273	40%	104	5%	661	12%	95	5%	1,613	99%
Total	3,148	100%	2,054	100%	5,512	100%	1,783	100%	1,635	100%

2014 HSC	Design & Technology		Engineering Studies		Industrial Technology		Software Design & Development		Textiles and Design	
Boys	1,828	58%	1,970	95%	4,751	89%	1,651	94%	23	1%
Girls	1,331	42%	109	5%	611	11%	111	6%	1,866	99%
Total	3,159	100%	2,079	100%	5,362	100%	1,762	100%	1,889	100%

2013 HSC	Design & Technology		Engineering Studies		Industrial Technology		Software Design & Development		Textiles and Design	
Boys	1,803	57%	1,964	96%	4,766	89%	1,491	93%	37	2%
Girls	1,362	43%	85	4%	599	11%	117	7%	2,096	98%
Total	3,165	100%	2,049	100%	5,365	100%	1,608	100%	2,133	100%

2012 HSC	Design & Technology		Engineering Studies		Industrial Technology		Software Design & Development		Textiles and Design	
Boys	1,835	57%	1,953	95%	4,589	90%	1,378	94%	36	2%
Girls	1,363	43%	98	5%	510	10%	93	6%	2,339	98%
Total	3,198	100%	2,051	100%	5,099	100%	1,471	100%	2,375	100%

The tables above indicate the following:

- The greatest gender discrepancy between male and female participation can be seen in Textiles and Design (98% female) and Engineering Studies (95% male).
- Design and Technology has the lowest gender discrepancy of TAS subjects with a difference of 20%, with boys having a higher participation rate than girls.

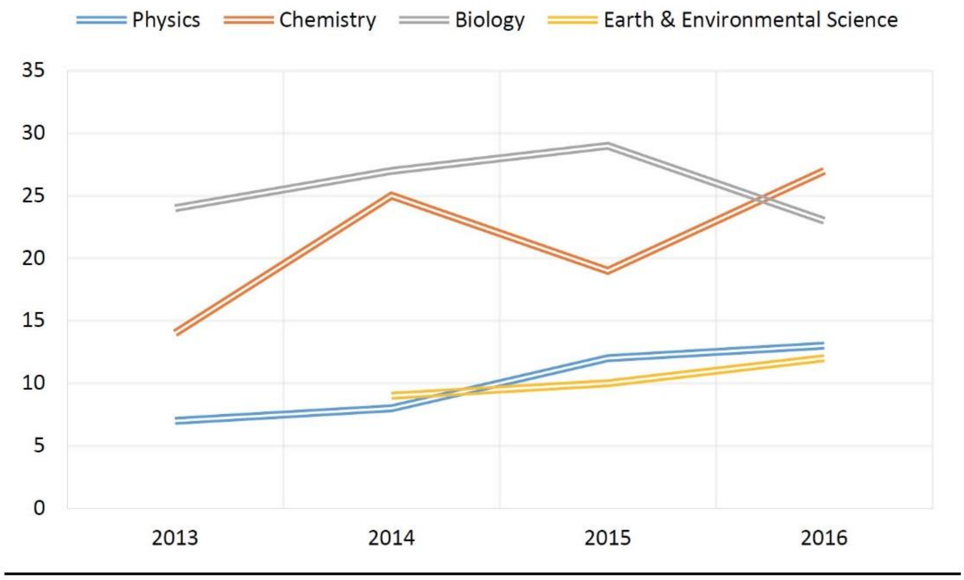
Wenona Participation Rates NSW HSC

The tables and graphs below outline participation in mathematics, science and TAS HSC courses at Wenona School over the last four years.

HSC Course	2016	2015	2014	2013
Mathematics	60	46	51	35
Mathematics Extension 1	40	29	26	21
Mathematics Extension 2	10	12	5	6
Mathematics General	33	37	39	58
Physics	13	12	8	7
Chemistry	27	19	25	14
Biology	23	29	27	24
Earth & Environmental Science	12	10	9	-

Engineering Studies	9	-	-	-
Design and Technology	7	14	-	11
Textiles and Design	17	19	25	16

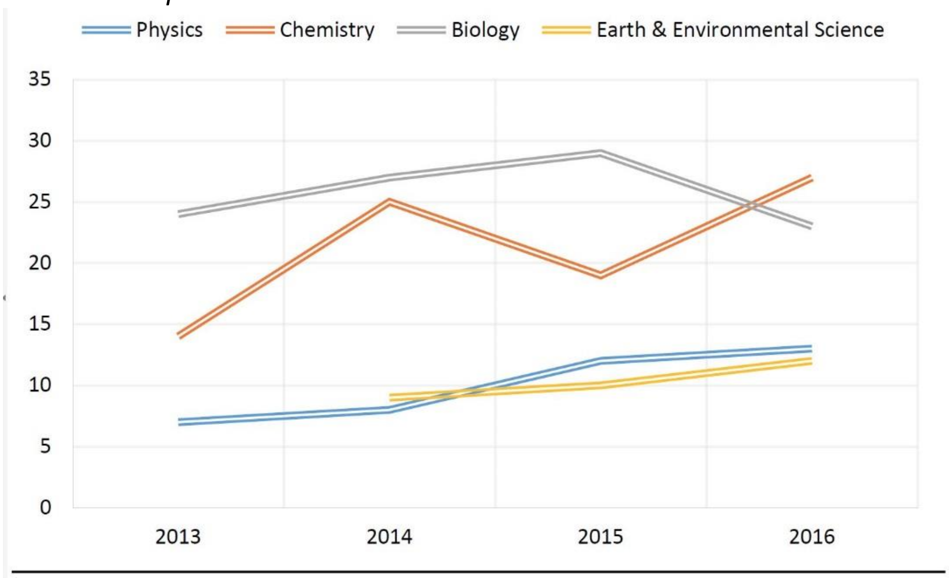
Mathematics Participation



The graph above indicates the following:

- There has been a downward trend in the Mathematics General course over the last four years.
- There has been an upward trend in Mathematics, Mathematics Extension 1, and Mathematics Extension 2 over the last four years.

Science Participation



The graph above indicates the following:

- Participation rates in Chemistry have been inconsistent over the last four years
- There has been an upward trend in Physics over the last four years
- There has been an upward trend in Earth and Environmental Science over the last three years (subject was not available in 2013)
- Biology has had an upward trend for three years and then declined in participation in 2016

Wenona Student Attitudes

As part of a longitudinal study into the impact of a STEM curricular and co-curricular program on girls' attitudes to STEM related subjects, girls in Year 7 to 12 completed an attitudinal survey. The survey questions were designed to measure the following student attitudes towards their subjects:

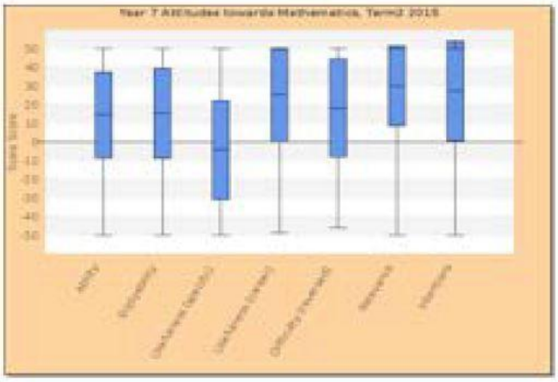
- Ability: students' perceptions of their own ability in a particular subject
- Enjoyability: innate enjoyment of a particular subject for the student
- Usefulness (specific): the extent that the student believes this subject is useful for careers in this discipline in the future
- Usefulness (career): the extent that the student believes this subject is useful for their chosen career in the future
- Difficulty: how hard the student perceives the subject to be
- Relevance: how relevant this subject is to the students' day to day life
- Intentions: if the student had freedom to remove this subject (not compulsory) would they continue to study it.

The following graphs represent student attitudes in the Years 7 to 10 Mathematics and Science courses in 2015. These graphs represent the first wave of data collection and therefore will be used as a measure of comparison for future cohorts.

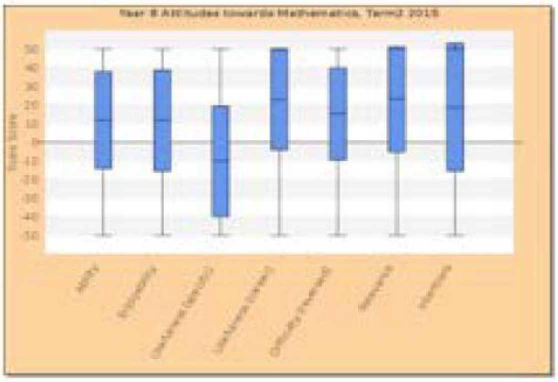
The blue area represents a standard deviation either side of the mean, thus representing 68% of the cohort in each course. Centre (0 line) represents neutral. The attitudes outlined above can be read from left to right on the graphs following.

Student Attitudes: Mathematics Years 7-10

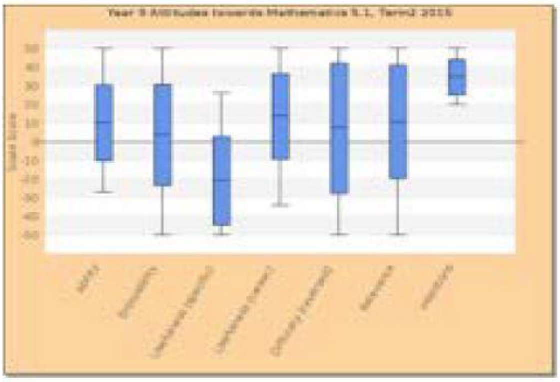
Year 7



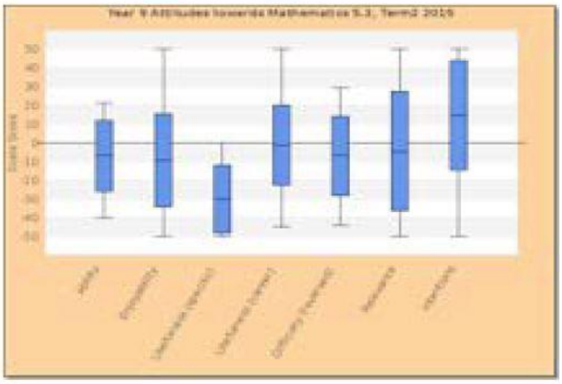
Year 8



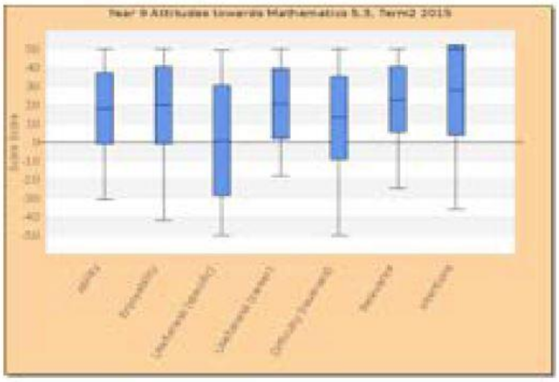
Year 9: Pathway A



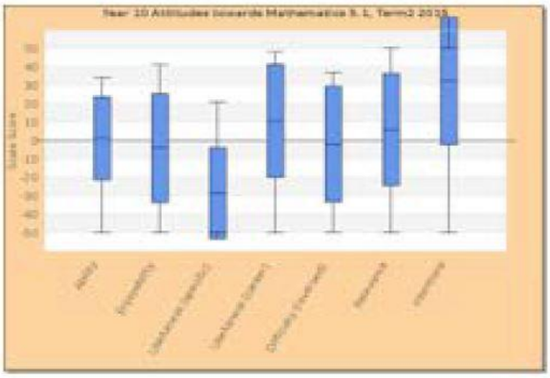
Year 9: Pathway B



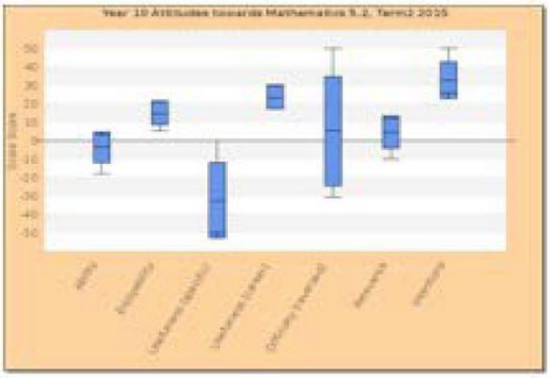
Year 9: Pathway C



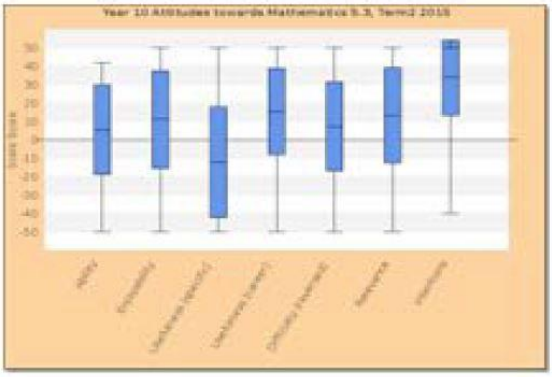
Year 10: Pathway A



Year 10: Pathway B



Year 10: Pathway C

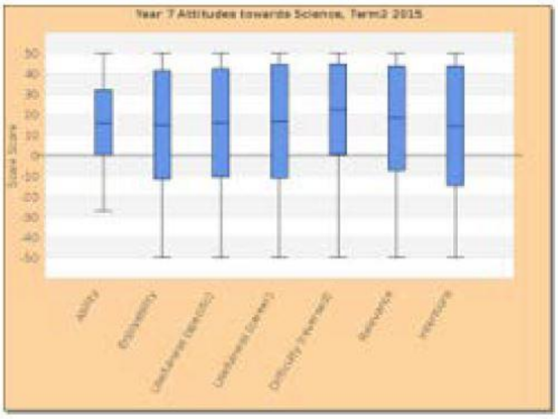


The graphs above indicate the following:

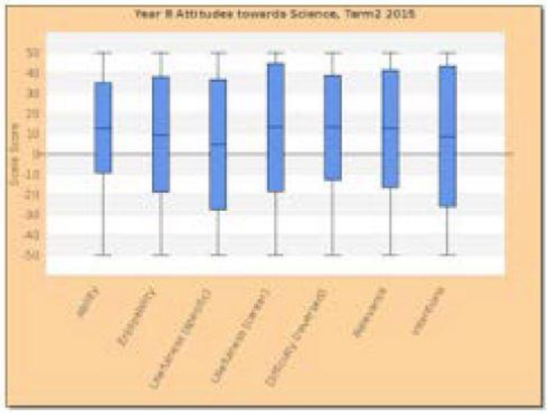
- Attitudes towards mathematics are lower in Year 9 than other year groups
- Regardless of ability, students across all year levels have high intentions with regard to the continuation of their study of mathematics in future years
- Students have a negative attitude towards specific careers in mathematics across all year levels, however, they have a positive attitude to the usefulness of mathematics in other careers

Student Attitudes: Science Years 7-10

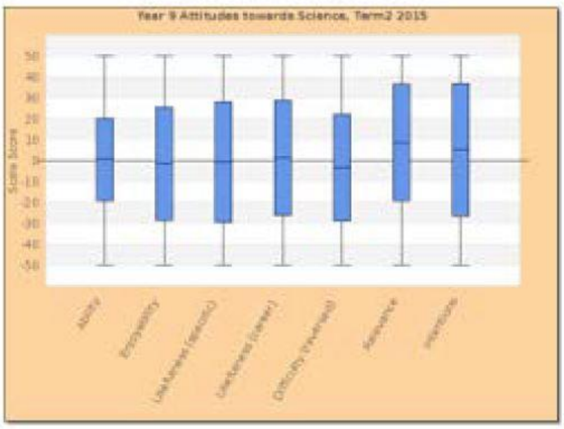
Year 7



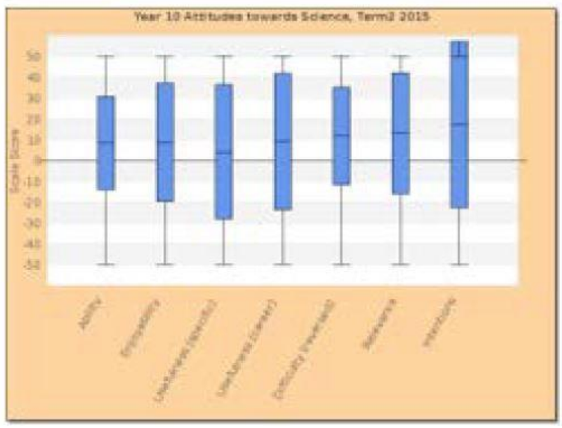
Year 8



Year 9



Year 10



The graphs above indicate the following:

- Overall, students in Years 7 to 10 have a positive attitude towards science.
- Attitudes in Year 7 Science are higher than the other year groups, whilst attitudes in Year 9 Science are lower than the other year groups.
- Intentions to continue with Science in Year 10 has the greatest range of responses.

Professional Learning Intervention in Science and Mathematics

The Deakin University team worked with Wenona mathematics and science teachers to explore pedagogies and curriculum aimed at engaging girls with STEM subjects and possible STEM futures. The science program focused on inquiry approaches whereby students generated models and representations to explore ideas, whilst the professional learning in mathematics aimed to build teacher resilience to increase their capacity to respond 'on the run' to student problem solving activities. The intention of these interventions was to add to the knowledge base of teachers and strengthen their personal characteristics to enable them to use this knowledge base. Both approaches explored the role of diagrams, graphs, sketches, and physical gesturing in the learning process of both science and mathematics.

The professional learning aspect of this study involved two main components:

a) Symbiosis between resilience and mathematical problem solving
b) Guided inquiry through Representation construction in science

Science

For the teachers of science, the initiative occurred in a series of topic cycles, with the Deakin team discussing with teachers their current practices, the directions in which they wished to take innovation, and details of the particular topics that would be dealt with. The Deakin team then provided resource material for these topics that exemplified the pedagogy and provided ideas for the shape of the topic sequence, and discussed and negotiated through examples the approach that would be taken. Details of the activities, and findings, will be described separately for the primary and secondary teachers.

Year 7 and 8 Science

Year 7 and 8 Science teachers were involved in an initiative which was aimed at establishing inquiry approaches to teaching science based on students constructing representations such as drawings, models, and role plays, in response to conceptual challenges. The teachers were cast as participants in an action learning community where they collaborated to design and trial ideas in their classes that had been introduced by the researchers. The teachers then reported back and further planned for the implementation of the approach. The aim of the approach was to have students more actively engaged in generating and discussing ideas, and focusing on the multi-modal literacies of science that underpin deeper learning.

Science Activities Undertaken

Following is a brief description of some rock cycle activities to illustrate the approach outlined above.

The initial exploration of rock types was undertaken by students in small groups who created a dichotomous key from a chosen collection of rock sets. An evaluation of the keys was undertaken at the small group level whereby each group self-assessed their own key in addition to evaluating another group's keys by testing it with an unknown rock.

A main learning outcome of the teaching sequence was for students to gain an understanding of the rock cycle whereby students get insights into the nature of the main rock types in addition to the processes by which they are individually formed and the processes by which one rock type can transform into another. Teachers did not supply an example of a canonical rock cycle, instead students were to critique different diagrammatic forms of the rock cycle to then construct their own rock cycle. In the following example, the teacher laid out seven different diagrammatic forms of the rock cycle in different locations in the classroom. In groups of three students they were to move around the room critiquing each rock cycle in terms of addressing the questions, 'What does it show well?' and, 'What it does not show well?'. Figure 1 shows a particular rock cycle with a transcript of a discussion between the group and their teacher following the group's critique of the rock cycle representation, illustrating how the critical analysis of the representation leads into deeper understandings.

T: *Looking at the cycle what can you tell me about it?*

S1: *It shows how everything is formed and connected.*

T: *When you say everything what do you mean?*

S1: *The types of rocks.*

S2: *And it is colour coded too.*

T: *Does that help?*

S2: *Yes, because if you follow the arrows you find what you are looking for.*

S1: *For example, both sedimentary and igneous rocks have similar processes that they can through heat and pressure form the metamorphic rocks* [pointing to the dark red arrows] *…it shows how they are connected to the metamorphic rock.*

S3: *…it gives you options about where to go.*

S1: *The second example is sedimentary rocks can melt to form magma, which when it cools becomes igneous rocks; the igneous though can become a sedimentary rock once again through erosion [tracing the path with a pen].*

T: *So erosion is leading from that one?* [pointing at igneous]

S1: *Connected to sediments to sedimentary…*

S2: *It's like a never ending cycle.* [point out various cycle on the diagram]

T: *Does it show weathering?*

S1: *It shows erosion but doesn't show weathering.*

T: *So does this help explain the ideas?*

S2: *Looking at it first it was kind of confusing but once you had time to look at it and follow the arrows it makes a lot of sense.*

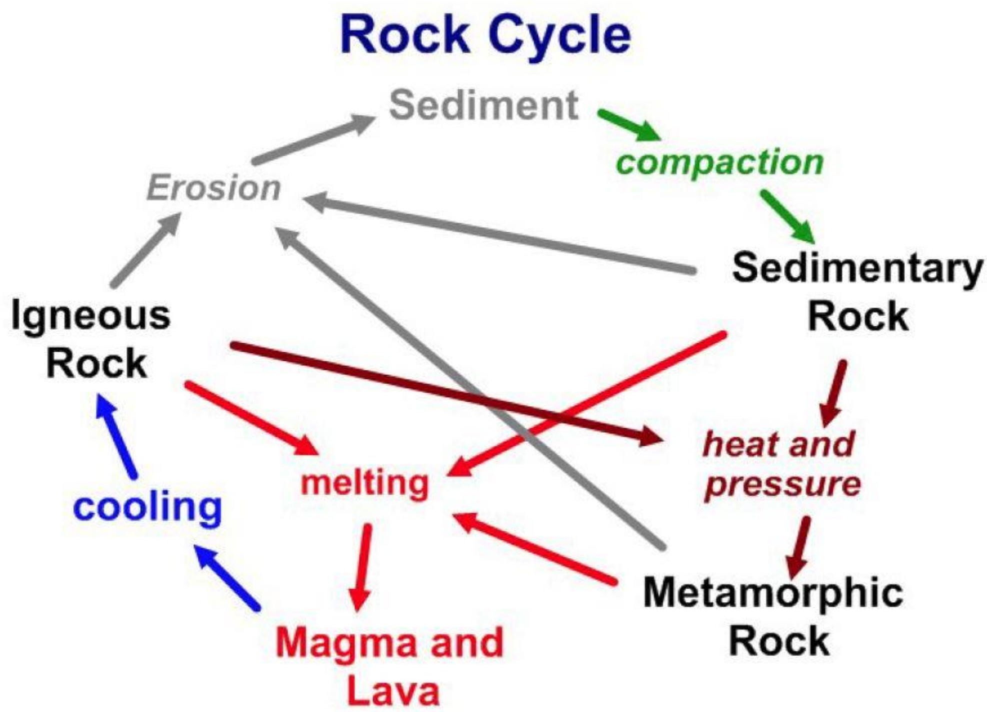


Figure 1: Small group critique of diagrammatic forms of the rock cycle

Student Learning

Two students were interviewed about their perceptions of changes in their science lessons. They perceived more practical activity, and more drawing and discussing:

> *'Heating and cooling particles … when particles are heated they get more energy so they can move around more. … we made our own models, drawing and imagining how they could work.'*
>
> *'I think, last year, we did not do very much experiment so it is a bit harder to visualise what we all learnt about, but this year we do a lot of it … we did so many time, we did a whole topic on scientific, like drawing it and other skills, that is the way … we usually do that like a practical experiment and then we come back and add the questions, like what happens and how is it?*

And it is good because at the same time like pushing you to figure it out yourself.'

One student made commentary on the use of multiple modes:

> *'[We use] diagrams and things…we did a lot of that when we were doing matter to explain what was going on…we have different particles, diagrams and different forms of state of matter and we have to focus on the positive and negative of each diagram…[Critique gives a] kind of better understanding of what we are actually seeing, all different ways to represent it and then we usually do our best way after that, like using information from the other one … You look at all the different ones, you remember the one is the best, then I will ask you to mix, match kind of the best diagrams so you just look at to make your own.'*

Teachers' Practice

Over the period of the study the teachers engaged with the inquiry approach over two topics. In interviews, based around the component map instrument, teachers described how their practices had changed as a result of the program, focusing particularly on the development of students' analytic and critical faculties. The changes indicated a significant shift in teachers' inquiry approaches and evidence of the use of the approach in their wider practice. Below are sample quotes illustrating the nature and extent of the change:

> *'I think the main difference is that my practice always used a lot of diagrams, graphs, pieces and of those representations has been a big part of the teaching … but the thing that I've changed the most is critiquing them.'*
>
> *'… if you did this frequently right from Year 7 across a range of the content, I think not only would you see an increase in their understanding, it's their willingness as they get older to see that as part of how they learn, but also I think it may have a powerful effect on their analytical skills.'*
>
> *'And that was good thinking and some good discussions that they had and you could hear them in their group talking and they were saying you know, "But the particles are too far apart, they're supposed to be sliding over each other but then they look like a*

gas." So they were pretty good at that, then when we got to the expansion stuff and they had to explain it in terms of particles, it was good because they could think in terms of particles what was happening at that level to explain what was invisible to them.'

'Yeah they're [becoming more sophisticated or in their critique] … they're becoming a lot more confident, you know I've got students who say to me "No I don't like that because." Before they were saying "I don't know about this one", now they're saying "No I don't like this, it doesn't show this, it doesn't show that".'

In the team meetings, teachers shared and compared ideas and experiences:

'It's good that we work as a team and that's probably what we're lacking at the moment. Because I learn more when we come together as a team when I hear, "Oh that's how you improved your way of showing representation of a particular thing". I might take it to this level and then someone else, I see has taken it one step more and goes "oh that's clever" or someone else did something and it didn't work and you'll know not to try that one.'

Year 6 Science

Three teachers from Year 6 were involved in this part of the research project. In the second half of 2015 the Year 6 classes were engaged in a unit on changes to matter, focusing on the use of particle models to explain phenomena such as dissolving. This then moved into project activities involving consumer science investigations such as paper towel absorption, and culminated in a class poster display and sharing of ideas. The three classes often utilised the shared space in the Year 6 area for joint activities and displays. The workshops with the research team were characterised by lively and enthusiastic discussion of science ideas and examples of high quality student work, including video taken of student presentations and displays, and discussion of the conditions for engagement as students constructed explanations of phenomena and planned and implemented investigative work.

Science Activities Undertaken

The Year 6 teachers focused on properties of and changes to matter, developing particle ideas to explain phenomena such as dissolving, and properties of a range of materials. Students were challenged to represent their ideas and these representations were discussed as a class, with students presenting using posters and iPad displays. A series of investigative projects were undertaken, with support for controlling variables and interpreting results. Figure 3 shows a report of an investigation into differential dissolving rates of food dye in hot and cold water. The explanation demonstrates a focus on using particle representations, and the premium placed on reasoning through evidence.

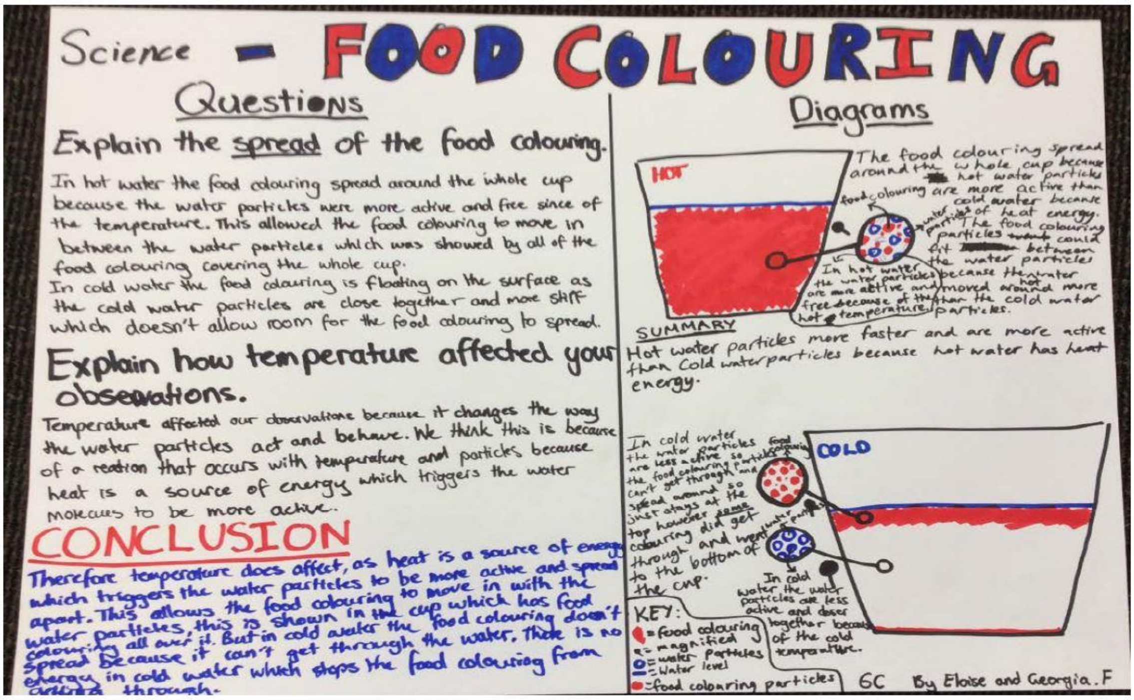


Figure 3: Student poster of an investigation into dissolving.

Student Learning

Interviews with two groups of students explored their experience of the matter unit and the consumer investigation. Students talked about the focus on investigation as being a recent phenomenon, and of how they were scaffolded to design experiments initially using 'the great paper towel experiment' (comparing the absorbency of different brands of paper towel) as a class activity.

> *'Doing it as a class was good because you could hear what the other people are thinking and doing.'*

Students described ideas they had learnt about particles – inter particle forces, how they are arranged in solids, liquids and gases '*we watched videos, went to websites*'. There was evidence, as they described their investigations, of imaginative and critical thinking about the science ideas. This included speculating about energy exchanges between particles as balls bounced to different heights.

'We used our iPads to take a video of the balls bouncing and played it frame by frame.'

One student investigated a cornflour mixture and developed an explanation of its behaviour that extended on internet information.

'I put together … it's a different type of liquid - a non-Newtonian liquid. And it's about viscosity and - how the shear forces change the results – like you punch it and the particles have no time to think but lock up - like I've drawn here [pointing at her explanatory diagram] so, like here, if you go slowly there's time for the fluid to get under your finger so you sink in.'

The students emphasised the freedom they experienced to choose, and think for themselves:

'What we did was completely up to us. We had to work out how the particles were arranged.'

'I like that we get to do our own experiments...we get a choice of what we do...the experiment…and how we do it.'

They commented on the value of the approach for them:

'…actually doing it. Using your hands. Discussing…it was good because everyone came up with different ideas.'

'[Drawing] makes sense in your mind. It really helped me think about it a lot more with the locking up and spreading [of the thixotropic corn flour mixture] It made me think about "what if this and what if that…" …helped me come to more conclusions.'

Teachers' Practice

In interview the primary teachers described what they saw as the key elements of the inquiry processes that were being instituted, and the change in their practice that had occurred.

'Students are challenged to support and develop their own representations…I think I really challenged them for that. They really have to justify everything now - well they have to because they're starting almost from scratch.'

'Individual students' learning needs are monitored and addressed. Yeah, I think that's gone up for sure, because they're all working on their own thing, and I think that is definitely high up on my importance.'

> *'I think the main benefits (of the approach) are the fact that they have to justify why they've come to certain decisions or conclusions about things, and it makes them think on a much more scientific level and not necessarily on either just a word level or even a linear level.'*

The teachers were critically reflecting on the teacher's role in the inquiry process:

> *'The area I need to develop is really at what point or time do I say if they are on the wrong track. Do I say: look this is the scientific understanding if I know it, this is your method and your way that you've explored this but scientifically this is the correct definition…or more acceptable model. So that's something I have to do to work out that nice balance to give them time to explore and talk and look at other peoples and then build their own construct and then to find the right time to say look you're really close you're on your way to doing that but this is the accepted model.'*

And on the professional learning process:

> *'I've said this already, a few feedback sessions with other things, I think this is the best PD I've ever had. I think because it was all hands on, it was all practical, there was no waste of time, we were talking to experts, we were able to feedback immediately, it wasn't a one off, I didn't have to catch a cab to the city to go to a course.'*

Mathematics

For the teachers of mathematics, the initiative occurred through familiarisation with how a complex but accessible task at the start of a topic can help to build many of the understandings students have difficulty with if a topic is commenced with 'teacher teaching'. Teachers also became familiar with how carefully selected / designed tasks can begin to develop understandings for subsequent topics. Teachers commenced by considering ways students might commence the task, what mathematical understandings might begin to emerge, and what actions the teacher might take to elicit further thinking. Crucial to this approach was student autonomy and spontaneity with the directions they take.

The approach was aimed at establishing a collaborative problem solving method to teaching mathematics based on students selecting what mathematics to use, how to use it, what representations to construct, and what each group of four students would share with the rest of the class during each of the reporting sessions during the task. The teachers were cast as participants in an action learning community where they collaborated to work out how to make groups of four students with 'similar paces of thinking' (rather than similar performance on class tests) analyse tasks to identify their mathematical content, prepare to implement tasks by first analysing them to consider what could occur, and then learn through discussions during subsequent trials of the tasks in different classes. Details of the activities, and findings, will be described separately for the primary and secondary teachers.

Year 7 Mathematics

The Year 7 teachers, including two first year teachers, were all involved in this initiative. For the first professional learning session, the group used a task supplied by the Deakin team which was easy to implement and drew student attention to mathematics as a creative process rather than only rules and procedures. The task raised student awareness of two constructs that are crucial to problem solving: assumptions and constraints. Teachers considered possible pathways, mathematics that might emerge, and responses the teacher might make. After watching the video excerpts on the second session, the Year 7 teachers focused more on the actions of the teacher than the actions of the students. Their attention shifted to focus on the students as the professional learning sessions progressed.

For the second and third professional learning sessions, teachers selected their own tasks that were not text book based. The Deakin team then assisted in adding 'twists' to these tasks to increase their complexity, and it became apparent to teachers in subsequent sessions that these twists increased the opportunities girls had for control over their mathematical decisions. The process of discussing tasks and looking at what to focus on when implementing them had already begun to shift the practice of some teachers as shown by the following interview comments:

> *'So when we were doing all those activities last year and having the lessons recorded that was really valuable having the instruction that you don't tell anything don't give anything away if they say a statement push it back on them with more questions. If they ask a question don't answer it directly but keep questioning them … I found that really helpful.'*

'[I have learnt more through] practice I think. The more I do these tasks the better I get at my questioning. I always thought my questioning was quite good. I always go deeper. I don't really stop at the answer I always say "Why?" "Is there another answer?" "Does anyone agree or disagree?" but my questioning is not so prescriptive any more it is a little more free.'

Teachers showed they were willing to take risks as they developed their practice. One teacher described how difficult it can be letting go of structured practice to develop a more open practice:

'Towards the end of the year when you started to give us these types of activities /ideas I found that [my previous very structured] lesson structure was completely broken up. I felt like I wasn't in control any more. That was hard at the beginning. I was going around to see what the groups were doing but the learning was mainly in their hands and it worked out a lot better than I expected it was going to be.'

Year 7 teachers then used the model below:

1. Select a task and plan implementation by exploring ways students might respond, mathematics that might emerge, and appropriate actions for the teacher that did not 'tell' or 'hint' about the mathematics the groups had decided to focus on.
2. One teacher implements the task in their class while other teachers observe student responses.
3. Debrief after the session about what students were doing, the mathematics that was emerging, ideas to elicit further student thinking, and anything else teachers needed before implementing the task in their own classrooms and videoing these sessions.

Teachers then reflected on what they have learnt and what they are still trying to find out more about. The following are some teacher comments that capture some of the changes made and ideas that are the present focus of attention:

'I have also enjoyed the way in which we do the activities in class because I have always thought that we need to give students the answer … eventually [that] there was an answer and I am used to at some point showing them what the answer is and directing them. Through these activities I have found that I don't have to do that and I have found that if I have faith in the students they will come to it themselves.'

> *'Not commenting on, like not giving the answer away, was really hard for me because I have just been so used to saying ah yes okay this is the way you do it.'*
>
> *'I have found it difficult at first to just say I don't know and just step away but now as you say I just nod and tell them I am nodding because I understand what you say not that they are right and I am finding that a lot easier.'*

Teachers reflected on what had been learnt.

> *'[with my structured traditional model] I found that yes it helped them get all the information and yes they did well in the exams and they learnt what they were supposed to learn but it wasn't learning that they could really engage in.'*
>
> *'The lessons that were recorded when I looked back on them there were lots of things I felt that I could improve on from where I was positioned in the lesson through how I was interacting with students to how I was responding to queries and that is when I realised I was answering too many of their questions.'*

Year 5 Mathematics

Interviews with Year 5 students were conducted after the students had undertaken three or four of the complex mathematical problem solving tasks. Girls were selected for interview on the basis that their teachers considered they were responding differently to mathematics in these tasks compared to the usual ways they responded to mathematics. These tasks have been shown to give students opportunities to think creatively whilst developing mathematical understandings when implemented through an 'Engaged to Learn' teaching approach to problem solving. This is a resilience building approach that leads to deep mathematical understandings and increases students' problem solving capacities. This approach involves collaborative group work and students taking control of the mathematical directions they take. Students learn more about the mathematics involved as they explain the mathematical thinking they have done to the rest of the class and consider the reports of other groups, whilst teachers ask questions to elicit further student thinking without providing mathematical input about the spontaneous focus each group takes. For each task the following cycles of activities are undertaken:

a) collaborative brainstorming in groups of four students with the same pace of thinking, so students can keep pace with each other during the development of new ideas;

b) priming of reporters so the group, not the individual, is accountable for what occurs;
c) reports to the class;
d) class member questions reporters, but do not contradict statements made or ask questions beyond what was presented (to help the reporter to feel emotionally secure during their report);
e) teacher valuing (not praising) of each report to amplify successes achieved;
f) the next cycle commences with collaborative group work.

Teachers do not tell, hint, or affirm. Instead they ask questions to assist groups to take their thinking further. This approach is designed to build resilience through the manufacturing of situations likely to increase student opportunity to develop new ideas together as well as offer support for students in order to increase their likelihood of producing and clearly communicating their group report. Teachers adapt this process to suit their own teaching practice and gradually include more features of this approach when they feel comfortable in doing so. The data presented below for Year 5 is excerpts of student interviews that demonstrate various aspects of how they have responded to the approach as implemented by their teacher.

Student Learning: Resilience and Confidence Building

Student control of what they achieve mathematically is crucial to the resilience building process as articulated by Year 5 girls interviewed:

> **I**: Can you tell me how you feel when you are doing any of these tasks where you are not doing something that you have already been told how to do- is that a fair enough way to say it?
>
> **S**: Yes (pause). Like when you figure out something that you think might work you feel really mature like you think that you can do things for yourself now.
>
> **I**: Feel really mature … What does it feel like to be really mature?
>
> **S:** Well you don't need the help of adults or teachers, you can do it by yourself and you think it is going to be right even though it may not be.
>
> **I**: Okay why do you think it is going to be 'right'?
>
> **S**: Because like you have a theory of a way to do it and you feel like there's no other way to do it
>
> **I:** Okay and do they mostly turn out to be ways that it is possible to do?
>
> **S:** Yeah.
>
> **I:** And when do you know?
>
> **S:** Well if it is worked out and…you…and you don't think there is another way sort of and you have got a suitable answer that you think is probably right.

This student response emphasises the importance of the ideas coming from the students and the effect of a feeling of control that leads to growth (maturity). It also draws attention to student responsibility for working out whether the mathematics they generate is reasonable. Such feelings were beginning to arise for this student by the time she was participating in the second task:

> *'I guess it [doing these tasks] sort of has helped me with different challenges with maths now because it hasn't been as hard as it was [before I did these tasks]'*
>
> *'I liked maths in general but I wasn't feeling very confident about it [before these tasks]'*
>
> *'I got my report on Friday and my mum compared it with my last one [which showed I] was quite good at art and languages and sport but this time it has completely changed. I have improved a lot academically and so I felt quite proud of how I had improved my maths because it has got so much better.'*

These student responses show how increased resilience can result from personal effort leading to success with overcoming mathematical challenges and improved ability to work with mathematics as a result.

The Frog Task, about three frogs jumping in straight lines towards a pond, was intended to develop big ideas about limits (getting closer and closer but never quite getting there) along with ideas about what was realistic (is it ever close enough to say the frog has reached the pond). Because different frogs were jumping a third, fifth, or tenth, of the remaining distance the girls were devising their own ways (including their own representations) to work with fractions, thus increasing their understandings of the meanings of fractions and the relationships between vulgar or common fractions and decimals. Different groups worked by using exact calculations and measurements and only later thinking more in bigger picture, and others started with a bigger picture approach or shifted towards this early on.

> *'With the frog one I kept thinking about number three, number five, not number ten because I found that one a bit tricky I kept on thinking about that one over and over again—I even had dreams about it—because you can't divide it, you can divide it the first time into ten equal parts then you can't do it the next time because then there would be decimals.'*
>
> *'Well I feel more relaxed because I know I am not being judged.'*
>
> *'Well I find them challenging but I like challenges and interesting*

and a bit more fun'

The Year 5 student interviews provided confirmation of increased resilience of some students and an additional confidence in their ability to learn mathematics. Student control in developing their own mathematical ideas was crucial to this process. The collaborative environment with the absence of mathematical pressure and judgment, and the open way the tasks were focused, were also contributing factors. The girls illustrated deep engagement and sometimes fascination with the mathematics that emerged from their work with the tasks and the enjoyment they experienced as they undertook them. Their retention of big ideas long after the task was completed was also demonstrated. These interviews demonstrate that the Year 5 team's approach to learning, as they planned, trialled, and reflected on how to change their practice, has had many positive impacts.

Figure 5 below shows the different foci taken by different student groups in responding to the fish task prompt which was a diagram of a fish similar to that drawn in Figure 5 with an arrow pointing to the head region saying 'the head is as heavy as four tails' and an arrow pointing to the central body area stating 'the body is as heavy as the head and the tail together'. The posed task was 'find all you can about the maths of such fish'.

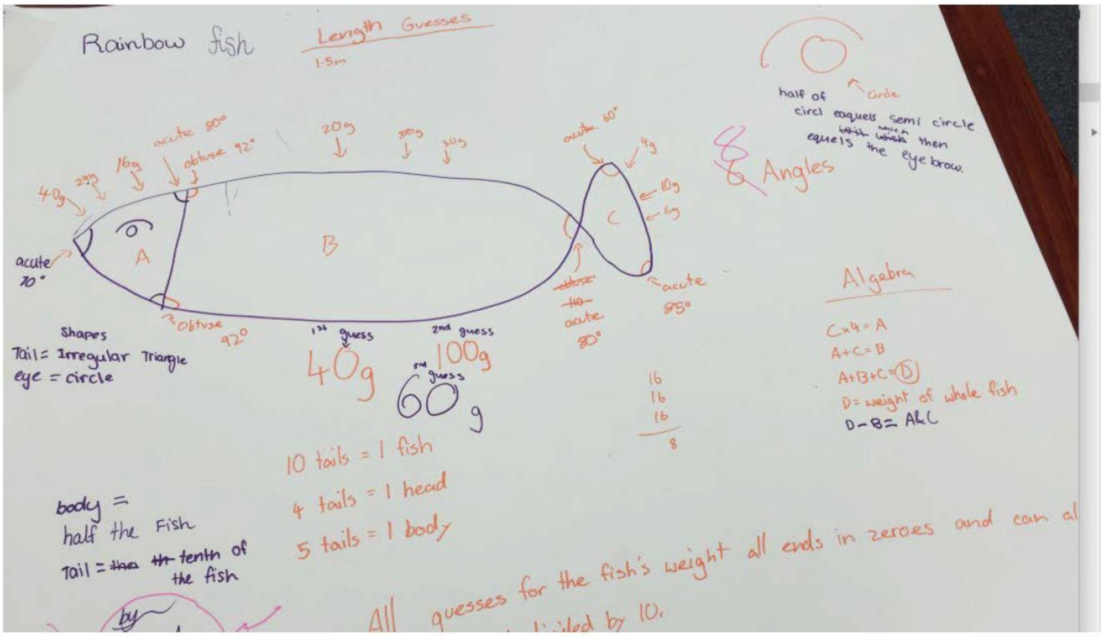


Figure 5: Fish Task Work Sheet: angles, diagrammatic shapes and patterns

The group whose work is shown in Figure 5 represents mathematical attention to at least four mathematical topics as girls explored this task: angles, plane figures, patterns, and the rudiments of algebra. The sentence at the bottom that is partly missing stated "All guesses for the fish weight all end in zero and can be 'timesed' and divided by 10'. There is evidence of developing ideas: for example, the use of letters as labels and letters in equations to represent relationships.

Discussion

The overall aim of this research project was to assess the impact of various strategies on girls' participation, enjoyment and achievement in STEM related curriculum areas. Throughout 2015 and 2016 various STEM activities were introduced or further developed at Wenona School. These included:

- Co-curricular: Car Restoration Club; Space Science Club; Maker Club; Solar Mini Sprint (Cars and Boats); Robo Cup; Zero Robotics.
- Curricular: Deakin University professional development intervention as well as other school based initiatives including the implementation of: Engineering Studies (Preliminary: 2015, HSC: 2016); computer coding and programming (Mandatory Technology - Year 8); Applied STEM Elective Course (Stage 5), Design Thinking Program (Years 7-10); Junior School Engineering Day and Junior School Science Day.

It was viewed by the school that if a difference was to be made to student learning outcomes in relation to STEM, then a broad and varied approach was necessary.

Girls' Participation and Attitudes Towards STEM

The student participation rates by gender, as expressed in the data collected from BOSTES, confirm that there is still a gender disparity in relation to stereotypical subjects studied by students for the HSC in NSW. Despite the reform that occurred during the 1970s, that made all curriculum areas available to girls, this data confirms that in relation to the higher levels of mathematics, the hard sciences, engineering and ICT courses, the representation of girls is extremely low in comparison to that of boys. However, the findings of this research have indicated that when a specific focus is put into place then this can have a positive influence on the participation of girls in these subject areas, as demonstrated through the increased participation in the more challenging mathematics and science courses at Wenona School. Whilst this study does not confirm a correlation between these two phenomenon, it does show that within this particular school context, where a STEM emphasis was put into place, participation rates did increase over the time of the intervention.

In support of these findings, are the positive attitudes reported by students in mathematics and science in Years 7 to 10. Generally, these students showed that they had positive attitudes in most domains; including: how they perceived their ability, their enjoyment of both subjects, the extent to which they perceived the study of these subjects would contribute to their chosen career in the future, and the relevance of the subjects. However, students in Year 9 were more negative in their attitudes than the other year levels, with Years 7 and 8 being the most positive groups in both subject areas. Of interest, students in Year 9 Pathway B, representing the middle level ability students, had a negative attitude in all domains, yet still were positive about studying this subject in the future. In most year groups across both mathematics and science, students believed that regardless of their ability, they had intentions to continue the study of these subjects in the future. However, whilst students could see that mathematics and science would be useful to their lives regardless of their chosen career, they demonstrated a negative attitude towards choosing careers in the mathematics and science domains in the future.

Professional Learning

The professional learning initiative that was put into place as part of this research study incorporated conceptual inquiry and investigative project based approaches (science) and extended problem solving tasks with other teachers observing and videoing each trial (mathematics). In both mathematics and science, the responses of the teachers showed a growing understanding of the pedagogy, growing confidence in implementing it, and in the learning payoffs for students. In mathematics, the change in focus from the actions of the teacher to the responses of the students was noticeable over time. For the secondary teachers there was evidence of the approach being used in classes beyond Year 7, and intentions to embed the approach into practice generally. For the primary teachers there was enthusiasm about the quality of student work that resulted, and there were frequent references to the excitement generated by students pursuing investigations and problem solving tasks, and representing and discussing key science and mathematics concepts.

The focus on deeper level learning, triggered by the nature of the representation challenges and open problem solving tasks, and supported by discussions between the teachers and the research team, was a key feature appreciated by the teachers. Enhanced learning in science and mathematics was evidenced by the examples of student work brought to the team meeting by teachers, and also by the teachers' descriptions of student responses, and by the student interviews. Enhanced learning included greater understanding of the role of representations (in science and mathematics), models in science, and in the primary case especially, enhanced investigative skills in science, and the diversity and appropriateness of applicability of strategies in various situations in mathematics.

There were differences in the ways the primary and secondary teachers approached the professional learning. Primary and secondary teachers in general expressed appreciation of the value of the professional learning. This appreciation included the opportunity to share ideas in teams, the development of new approaches to teaching, and the payoff in terms of student learning. Once the secondary mathematics teachers decided to take up a model similar to the Year 5 teachers, and spend their professional learning block deciding on, planning for, implementing, observing, and debriefing about student responses to the tasks, secondary teachers in general began to benefit more from the professional learning. Primary teachers in Year 6 undertaking professional learning in science, and in Year 5 undertaking professional learning in mathematics, were immediately ready to participate, share their videos and the work of their students, and discuss what they could learn from them about how learning was occurring. Amongst these teachers were some who immediately read and discussed literature provided. This immediate acceptance that there was something valuable to them and their students on offer meant changes in their practices were more evident earlier, and were greater in magnitude over all.

The success with the mathematics group in shared viewing of a lesson and focusing on student learning provided a potential way forward towards acceptance of the idea of sharing and discussing practice, as a pathway to wider video use. In science, personal sharing of snippets of video, and verbal accounts of representational challenges accompanied by examples of student work, were also successful. Working with teachers to develop trust, and confidence in the value of such shared practice, is an important program that will pay dividends in professional learning.

Research to Practice Impact

There are many takings from this research that can be both further developed within Wenona School as well as other schools wishing to implement similar change. In particular, the need to professionally develop teachers in their practice of teaching mathematics and science as well as challenging stereotypical ideas about subject offerings and selection, particularly in the girls' school context, will be vital in making a difference to girls' participation and performance in STEM related areas of education. Girls must build an identity where they both feel the part as well as the self-efficacy required to be successful STEM learners. Developing teachers to work and plan collaboratively as well as being open to feedback and able to change teaching practice are all vital professional learning needs that must be developed in a safe and supportive school environment.

The interventions and analysis of this impact cannot stop with the conclusion of this research project. Instead, this project marks the beginning of intervention, and methods such as the tracking of trend data and the longitudinal collection of student attitudes will be important tools in assessing the impact of this intervention over time. Likewise, the tracking and analysis of data concerning student post-school destinations and subsequent careers will also be vital in assessing the life-long impact of a school led STEM intervention program.

Conclusion

It is hoped that this research project can offer solutions to improve the educational outcomes for girls in all areas of STEM, not just at Wenona but also more broadly. There is a significant gender disparity with regard to tertiary education and employment in these fields; however, to address these issues, it is firstly important to look at the primary and secondary educational setting in order to assess if specific strategies can change girls' perception of and skills in STEM fields, thus facilitating more girls into these areas in their post-school lives. It is hoped that this becomes the focus of many schools, and that the immediate need to address this issue in relation to girls is recognised.

References

Archard, N. (2013). Women's participation as leaders in society: an adolescent girls' perspective. *Journal of Youth Studies, 16*(6), 759-775.

Archard, N. (2012). Adolescent girls and leadership: The impact of confidence, competition, and failure. *Journal of Adolescence and Youth*, 17*(4),* 189-203.

Baker, J. (2010). Great expectations and post-feminist accountability: young women living up to the 'successful girls' discourse. *Gender and Education, 22*(1), 1-15.

Cann, R. (2009). Girls' participation in post-16 mathematics: a view from pupils in Wales. *Gender and Education, 21*(6), 651-669.

Dweck, C. S. (2006). *Mindset: The new psychology of success*. New York: Ballantine Books.

Eccles, J. S, & Wigfield, A. (2002). Motivational beliefs, values, and goals. *Annual Review of Psychology, 53*(1), 109-132.

Education Council (2015) *National STEM School Education Strategy: A Comprehensive Plan for Science, Technology, Engineering and Mathematics Education in Australia.* Retrieved from www.educationcoucil.edu.au 23 May 2016.

EOWA. (2012). *EOWA 2012 Australian Census of Women in Leadership*. Sydney: Equal Opportunity for Women in the Workplace Agency.

Foster, V. (1992). Different but Equal? Dilemmas in the Reform of Girls' Education. *Australian Journal of Education, 31*(1).

Furtak, E. (2006). The problem with answers: An exploration of guided scientific inquiry teaching. *Science Education*, *90*(3), 453– 467

Jones, L. (1995). Confidence and Mathematics: A gender issue? *Gender and Education, 7*(2), 157-166.

Kenway, J. (1990). *Gender and Education Policy: A call for new direction.* Melbourne: Deakin University.

Kirschner, P., Sweller, J., and Clark, R. (2006). Why minimal guidance during instruction does not work: An analysis of the failure of constructivist, discovery, problem-based, experiential, and inquiry-based teaching. *Educational Psychologist*, *41*, 75–86.

Lloyd, J., Walsh, J., & Yailagh, M. S. (2005). Sex Differences in Performance Attributions, Self-Efficacy, and Achievement in Mathematics: If I'm so Smart, Why Don't I Know It? *Canadian Journal of Education, 28*(3), 384-408.

McEwen, A., Knipe, D., & Gallagher, T. (1997). The impact of single-sex schooling on participation and achievement in science: A 10-year perspective *Research in Science and Technological Education, 15*(2), 223--233.

Moyle, K., & Gill, J. (2005). Just how far have we come? A retrospective on girls' education and an analysis on the present situation. *Redress, 14*(2), 2-12.

Patton, M. Q. (2002). *Qualitative Research and Evaluation Methods. Third Edition*. Thousand Oaks, CA: Sage Publications.

Sarkar, M, Tytler, R, & Palmer, S (2014). *Participation of women in engineering: challenges and productive interventions*. Melbourne: Deakin University.

Sax, L. (2006). *Why Gender Matters. What Parents and Teachers Need to Know about the Emerging Science of Sex Differences*. New York: Random House.

Skelton, C. (2010). Gender and achievement: are girls the "success stories" of restructured education systems? *Educational Review, 62*(2), 131-142.

Tytler, R., Prain, V., Hubber, P., Waldrip, B., (Eds.) (2013). *Constructing representations to learn in science*. Sense Publishers, Rotterdam, Netherlands 2013 Retrieved from www.macict.edu.au/blog/2013/01/robotics-in-education.

Van-de-gaer, E., Pustjens, H., Van-Damme, J., & DeMuster, A. (2004). Effects of single-sex versus co- educational classes and schools on gender differences in progress in language and mathematics achievement. *British Journal of Sociology of Education, 25*(3), 307-322.

WGEA, (2016). Gender Pay Gap Statistics, March 2016. Sydney: Workplace Gender Equity Agency.

Williams, G. (2013). Grouping: Successes, surprises, and catastrophes. In Andrea McDonough, Anne Downton, and Leicha Bragg (Eds.) *Mathematics of the Planet Earth* (pp. 76-84), Brunswick, Victoria: The Mathematics Association of Victoria

Yates, L. (1993). *The Education of Girls: Policy, research and the question of gender*. Hawthorn Victoria: Radford House.

Ziegler, A., & Heller, K. A. (2000). Conditions for Self-Confidence Among Boys and Girls Achieving Highly in Chemistry. *Journal of Secondary Gifted Education, 11*(3), 1-10.