

ARGUMENTATION, DECISION-MAKING AND SOCIOSCIENTIFIC ISSUES

Vaile Dawson¹, Katherine Carson¹, Grady Venville²

¹Curtin University, Australia

²University of Western, Australia

ABSTRACT

The purpose of this research was to investigate the impact of classroom argumentation on genetics based socioscientific issues on high school students': 1) argumentation skills, 2) informal reasoning type and 3) conceptual understanding of genetics. The research occurred in three Western Australian high schools. The research design was quasi-experimental, with an intervention in which teachers embedded lessons on argumentation within their regular genetics course. In each school the experimental classes implemented the intervention and the control classes did not. Data collection consisted of a pre- and post -instruction student survey, classroom observations and teacher and student interviews. The results showed that in all three schools, students instructed in argumentation improved on average significantly better than students in the control classes in argumentation and informal reasoning. In two of the three schools students in the experimental class also improved significantly more in their conceptual genetics understanding.

Keywords: Socioscientific Issues, Argumentation

BACKGROUND

In order for high school students to develop into well informed, scientifically literate members of society, it is necessary for them to debate science topics of relevance and importance to both themselves and society (Driver, Newton & Osborne, 2000). They need to be able to voice opinions based on scientific understandings, demonstrate logical patterns of reasoning and support their arguments with sound scientific evidence (Sadler & Zeidler, 2005a; 2005b). This rhetoric assumes a positive and complementary association between argumentation and student understanding of science (Sadler & Fowler, 2006). There is also the assumption that student involvement in argumentation based on real life issues is likely to contribute to conceptual scientific understanding and also that an understanding of science is essential for the development of quality arguments by students.

Argumentation is a term which refers to the process of debate and structured discussion used to reason about problems. Toulmin (1958) designed a model which can be used to teach students and teachers the skills of argumentation and how to analyse and evaluate students' arguments about socioscientific issues. After performing a review of research related to argumentation in science education, Sadler (2004) revealed that the interaction between argumentation and conceptual understanding is complex. Some studies showed a positive association between reasoning and conceptual understanding while other studies did not. Sadler argued that these studies provided confusing information about whether students can engage in meaningful argumentation in the classroom, whether the process improves students' conceptual understanding of science content and what degree of understanding is adequate for student involvement in the process of argumentation.

Scientific topics where individuals and groups in society hold conflicting and often mutually exclusive viewpoints are known as socioscientific issues. The decisions about these issues may have social, ethical, political and economic consequence. In order to be able to develop into informed decision makers in the future, young people need to be made aware of not only the practical applications of science in the real world but also the complexities of socioscientific issues. Examples of socioscientific issues which affect our society and are likely to impact on the lives of young people both now and in the future are; climate change, sustainable development, food and energy resources, health care allocation and population control. Socioscientific issues in which young people will need to evaluate the risks and benefits on a more personal level include using a mobile phone, reproductive control and eating genetically modified food.

The purpose of this research was to investigate the interaction between high school students' argumentation skills and informal reasoning about genetic socioscientific issues and their conceptual understanding of genetics.

The context of genetics education was selected for three reasons. First, recent and current advances within the field of genetics have led to societal concerns and increased media coverage. Examples of genetic socioscientific issues include production and consumption of genetically modified food, development of 'designer babies' where pre-implantation genetics testing is used to select embryos free from particular genetic disorders and genetic testing for insurance purposes. Second, the topic of genetics was chosen for a technical reason. Within Western Australia where the research was performed, genetics is mandated in the science curriculum documents and is usually taught in year 10, which is the last compulsory year for science teaching. Hence it was expected that the findings would be of interest and significance to many science teachers. Third, through our discourse with science teachers we have noted their concern about how to deal with unavoidable yet sensitive issues that arise in the classroom when teaching about diagnosis, prevention and treatment of genetic diseases.

The findings put forward in this paper are part of a larger research study currently being conducted by the authors. Addressed in this paper are the following research questions:

1. How does an intervention based on argumentation, impact on the structure of Year 10 students' argumentation and type of informal reasoning about a genetic socioscientific issue?
2. How does an intervention based on argumentation, impact on Year 10 students' conceptual understanding of genetics?

In the conclusion we will discuss some methodological issues arising from this study, as well as offer some suggestions for those involved in similar classroom based research.

RESEARCH METHOD

The research method used was a mixed method of data collection (Cresswell & Plano Clark, 2007). Data was collected using both qualitative and quantitative methods. The research was conducted in three schools, with four science teachers taking part with their Year 9 or Year 10 students (aged 13 – 15 years old). The schools were selected to be representative of the three school types in Western Australia. These classes were studying genetics when the data was collected. Each teacher in the experimental group took part in a professional learning session which focussed on argumentation, decision-making skills and genetic socioscientific issues. These teachers then explicitly taught and modelled the process of argumentation to students over several lessons. Students were introduced to all parts of an argument including claims, data, warrants, backings, qualifiers and rebuttals. Students individually worked through writing frames about two genetic socioscientific issues. The writing frames contained questions to scaffold the structure of a good argument. Students also took part in whole class discussions and small group work to further develop and justify their decisions about socioscientific issues based on genetically modified food and cystic fibrosis (Dawson & Venville, 2010).

Sample

A summary of the school type, teachers' backgrounds and experience, professional learning, classroom intervention, genetics topics and data sources for each school is provided in Table 1.

Table 1: Brief description of schools

	School 1	School 2	School 3
School Description	Co-educational Catholic independent	Co-educational Catholic independent	Co-educational wholly government funded
Experimental group Teacher/s	Male biology teacher (19 years experience)	Female biology teacher (7 years experience)	Female biology teacher (7 years experience) Female, non-biology major teacher (15 years experience)
Control group teachers	Male biology teacher (7 years experience) Male biology teacher (5 years experience)	Male biology teacher (8 years experience)	Female biology teacher (1 year experience)
Experimental group	Year 10 n=46	Year 9 n= 23	Year 10 n= 58
Control group	Year 10 n=46	Year 9 n=50	Year 10 n=21
Professional learning	Brief (90 minute) professional learning on socioscientific issues, argumentation, decision-making	Two days on genetic diseases, socioscientific issues, argumentation, decision-making	Two days on genetic diseases, socioscientific issues, argumentation, decision-making
Classroom Intervention	2 x 50 minute lessons including small group and whole class argumentation Writing frames	3 x 50 minute lessons including small group and whole class argumentation Writing frames	2 x 50 minute lessons including small group and whole class argumentation Writing frames
Genetics topic	40 lessons on: cells inheritance genetics genetic diseases	24 lessons on: cells reproduction genetic variation inheritance ethical issues	28 lessons on: reproduction inheritance genetic variation natural selection ethical issues
Data sources	Pre/post student survey Classroom observation Post student interviews Post teacher interviews Writing frames Teacher's plans	Pre/post student survey Classroom observation Post student interviews Post teacher interviews Writing frames Teacher's plans	Pre/post student survey Writing frames Teachers' plans

Data Sources and Analysis

The research used a quasi experimental design with a pre- and post-test to determine the effect of teaching argumentation on students' argumentation skills, informal reasoning type and conceptual understanding of genetics. Students in the experimental group were taught their regular genetics course as well as argumentation, by teachers who had participated in professional learning. Students in the control group were taught only the genetics course, by teachers who had not participated in professional learning. The experimental group and control group of students were from the same school and the same year group.

Students' argumentation skills and informal reasoning type were assessed before and after their study of genetics. Analysis was performed on students' written responses to a socioscientific issue based on 'designer babies'. Students were given a scenario, where for the cost of \$10,000 scientists could create for parents a disease free embryo. Students were asked their opinion on whether this should be allowed and were offered choices of 'yes', 'no' and 'I don't know'. They were then asked to write as many reasons as possible to justify their decision.

Analysis of students' written responses was performed using two different methods. The first was based on the complexity of the student's argument and was determined using a classification scheme based on Toulmin's argumentation pattern (TAP) (Dawson & Venville, 2009). Students' written arguments were given a level or score from 0 to 4, with a higher level indicating a higher level of complexity. The level depended on the presence

of claims (decision only), data (evidence to support claims), warrants (relating data to claim), backings (assumptions to support data/warrant) and qualifiers (conditions under which claims or data are true). No response was given a score of 0. Table 2 summarises the conditions required for each level to be obtained.

Table 2: Conditions required for argumentation levels

Level	Presence of					
	No response	claim	data	warrant	backing	qualifier
0	✓					
1		✓				
2		✓	✓	or ✓		
3		✓	✓	✓	✓	or ✓
4		✓	✓	✓	✓	✓

The second method of analysis was based on the type of informal reasoning used by each student. The informal reasoning type was determined using a method previously established by Sadler and Zeidler (2005a) and Dawson and Venville (2009). Students' written responses were given a score of 0 to 3. Responses were classified as intuitive (personal, gut response), emotive (care, empathy, concern for others) or rational (logical, using appropriate scientific language, evaluating risk). Table 3 shows the informal reasoning type required for each level.

Table3: Informal reasoning type and levels

Level	Informal Reasoning Type
0	No response
1	Intuitive Only
2	Emotional ± Intuitive
3	Rational ± Emotional/Intuitive

All students' written responses were coded blind by two experienced researchers. The pre- and post-test argumentation and informal reasoning levels were entered into an SPSS database and analysed statistically. Using a Wilcoxon Signed Rank Test, the difference in levels before and after teaching genetics for each group was determined. A Mann Whitney U test was used to analyse the difference between the experimental and control group.

A written survey was used to assess the conceptual understanding of each student before and after studying genetics. The survey had a maximum score of 52 and consisted of 18 multiple choice and three short answer questions. This addressed research question 2. In the short answer section, students were questioned about their understanding of the relationships between different genetics concepts such as DNA, genes and chromosomes, as well as their understanding of the principles of inheritance. Using a repeated measures ANOVA, the difference between the pre- and post-test scores for the experimental and control groups were analysed.

RESULTS

Argumentation Quality

For each of the three schools, using the students' written responses to the socioscientific issue, the pre- and post-instruction quality of the argument was compared for the experimental and the control group. Before instruction, overall the incidence of Level 1 and Level 2 was the most common in both the experimental and the control groups. Post-instruction, the experimental group showed a greater increase in the incidence of Level 3 and Level 4 when compared to the control group, which showed either a very small or no increase in Level 3 and Level 4 argument quality.

An improvement in argumentation quality in all three experimental groups between pre- and post-instruction was shown to be statistically significant, using a Wilcoxon Signed Rank Test (school 1, $p < .001$, school 2, $p < .05$, school 3, $p < .05$). There was no significant improvement shown in the control groups of school 1 and 3, but there was a slight improvement in school 2 ($p < .05$). A Mann Whitney U Test showed the difference between pre- and post-instruction levels in the experimental group in school 1 and school 3 to be significantly better than the control groups (school 1, $p < .01$, school 3, $p < .01$). It was not possible to obtain a result for school 2 as the experimental and control groups were not equivalent.

The following is an example from a student in the experimental group in school 2, which illustrates the improvement in argument quality from pre- to post-instruction.

Student 7: Pre – I don't know. I think it should be allowed to take out genetic diseases but not to make your baby different looking. (Level 1, claim only)

Student 74: Post – I don't know (claim) because in some ways it is right in being able to take out genes for genetic disorders (data) because it will save the parents and child a lot of pain (warrant) I think you shouldn't be able to change things such as sex, intelligence, height and hair colour (qualifier) because it shouldn't be the parent's decision and is interfering with nature (data). If everyone had designer babies then a lot of people's hair colour, height etc would be the same and not unique to a person and special (backing). (Level 4, claim, warrant, data, qualifier and backing)

Informal Reasoning Type

For each of the three schools, the informal reasoning types were compared between pre- and post-instruction and between the experimental and control groups. In all three experimental groups, the incidence of rational informal reasoning (Level 3) increased post instruction. Using a Wilcoxon Signed Rank Test, this improvement from pre- to post-instruction was shown to be statistically significant for all three experimental groups (school 1, $p < .01$, school 2, $p < .05$, and school 3, $p < .05$). No significant improvement was seen in the three control groups. A Mann Whitney U Test showed the post-instruction levels for the experimental groups compared to the control groups were significantly better in school 1 and school 3 (school 1, $p < .05$, school 3, $p < .001$). It was not possible to obtain a result for school 2 as the experimental and control groups were not equivalent.

The following are two examples from students in the experimental group of school 2, which illustrate the change in informal reasoning type from pre- to post-instruction.

Student 68: Pre – No. because it is not right to play God. (intuitive)

Student 68: Post – No. There may be serious errors if the baby doesn't develop properly and ends up with a disorder and it is not right to play God and you shouldn't do this because it has not been tested and they aren't 100% sure it will be disease free. (rational/intuitive)

Student 66: Pre – No. I think the baby should be naturally born because the average parent would want their son/daughter to look like them. (emotive)

Student 66: Post – Yes. This discovery (sic) could be the cure for cancer and diseases. Only the rich would be able to afford this designer babies project (sic). Scientists need to do a lot of research to analyse (sic) the risks involved. (rational)

Conceptual Understanding

Analysis using a repeated measures ANOVA showed there was a statistically significant increase over time in the mean genetic scores (from the student survey) of all three experimental groups and the control groups of school 1 and 2 ($p < .001$). This improvement is expected because all classes had been taught genetics during this time. It is concerning that the control group of school 3 did not improve despite their study of genetics. The repeated measures ANOVA showed the mean genetics score of the experimental group improved significantly more than the control group in school 1 ($p < .05$) and school 3 ($p < .001$). There was no significant difference between the experimental group and control group's pre- and post-study of genetics mean genetics score in school 2. It may be important to note that the students in the experimental group in school 2 were very social and talkative. This may have impacted negatively on their learning. For each of the 3 schools, the mean genetics scores and standard deviation before and after studying genetics for the experimental and control groups is summarised in Table 4.

Table 4: Descriptive statistics for the pre-instruction and post instruction genetics knowledge scores for the control and experimental groups

Group treatment	Time	School 1		School 2		School 3	
		Mean (out of 52)	SD	Mean	SD	Mean	SD
Control	Pre-instruction	10.70	4.34	8.55	3.56	7.81	3.52
	Post-instruction	17.74	8.98	17.92	8.82	8.81	5.61
Experimental	Pre-instruction	12.52	5.76	7.15	2.60	7.91	3.69
	Post-instruction	22.50	7.99	15.60	7.17	16.48	6.22

CONCLUSION AND IMPLICATIONS

Results from this research show that in all three schools, an intervention that includes teacher professional learning on argumentation, socioscientific issues and decision making, followed by explicit classroom instruction on argumentation within students' genetics classes, significantly improve the quality of students' arguments and rational informal reasoning about socioscientific issues. These findings are significant, as they indicate a targeted professional development for teachers and a brief classroom intervention can improve students' argumentation skills and change their informal reasoning from intuitive to rational. Also in two out of three schools, students taught argumentation improved their conceptual genetics knowledge significantly more than students not taught argumentation. This finding indicates that improvement in argumentation skills may facilitate conceptual understanding.

Several methodological issues and questions related to this research study need to be considered. These issues are:

1. Different teachers taught the experimental and control groups in each school.
2. Students were not randomly assigned to groups.
3. The intervention was similar but different across cases.
4. The intervention was modest.
5. Students' argumentation skills and informal reasoning were determined through written responses.
6. Is change in argumentation sustained and/or transferable to different contexts?

These methodological issues relate largely to the nature of school structures in Western Australia where the study was conducted. We are ethically obliged as researchers to cause minimal disruption to teachers and students, hence such issues will arise.

In Western Australia students attend high school from Year 8 to Year 12 and students are typically 12 to 17 years old. High school science teachers usually specialise in biology, chemistry or physics in their university degree and teach this specialty in Years 11 and 12. In Years 8 to 10, science teachers typically teach all science topics (biology, chemistry, physics and earth science) and stay with the same students all year. All four teachers in our research who taught argumentation to the experimental groups were biology specialists who volunteered after being approached by the researchers. In each school every effort was made to keep the experimental and control groups comparable. In each school both groups attended the same school, studied the same genetics topics, for the same length of time, in the same year and were all taught by biology specialists.

Despite our efforts, the differences in genetics understanding between groups may be in part to the difference in teacher expertise. We attempted to minimise this effect by the control teachers being biology specialists. We could not control for years of experience. To address this issue, more recently we identified two schools where classes change teacher each term, so all students are taught genetics by the same biology specialist teacher. Recently we have completed the argumentation with three teachers from these schools. The same quasi-experimental design was used, with both the experimental and control groups being taught by the same teacher. In each school, the teacher taught the control group the genetics topic. Following this, the teachers took part in a professional learning session on argumentation, socioscientific issues and decision making. They then taught the argumentation group the same genetics topic as well as some lessons on argumentation. Data analysis for these schools is currently underway.

The improvement in genetics understanding for the experimental groups in school 1 and school 3 could also be explained by the students being more academically able than the students in the control group. Due to the structure of the schools, we cannot randomly assign the students and teachers to the experimental and control

groups. Although the mean genetics understanding score for each group indicated no significant difference prior to instruction, this explanation cannot be excluded.

All four teachers who taught the experimental groups took part in similar professional learning experiences of varying length. They then designed and implemented their own argumentation lessons, using writing frames and lesson plans supplied by the researcher. Each teacher differed in their approach to the argumentation lessons and it is not possible to determine how this variation affected the students' argumentation skills.

The classroom argumentation intervention in each case was brief and it is possible that a more prolonged intervention may have produced more conclusive results. In each school the argumentation intervention for the experimental group took place over two to three lessons, within a genetics topic of between 24 and 40 lessons. During that same time, the control group studied the genetics topic only. At the end of the genetics topic, each group took part in a formal school examination on their understanding of the genetics content. We did not want to risk disadvantaging the experimental group as they needed to study the same school science curriculum as the control group.

In this study, students' argumentation quality and informal reasoning type were assessed using individually written responses to a genetics socioscientific issue based on creating a 'designer baby'. It is not known whether this written response is indicative of a student's ability to construct a verbal argument, either within their science classroom or in another context.

Finally, the desired outcome of developing students' argumentation skills is that they use these skills when evaluating and justifying their decisions about socioscientific issues later in life. It is hoped that the improvement in argumentation skills and informal reasoning is both sustainable and transferrable to new contexts. In late 2009, we retested students nine months after their argumentation intervention using a different genetics socioscientific issue and an environmental socioscientific issue. Data analysis is currently underway.

REFERENCES

- Cresswell, J. W., & Plano Clark, V. L. (2007). *Designing and conducting mixed methods research*. Thousand Oaks, CA: Sage.
- Dawson, V.M. & Venville, G. (2010). Teaching strategies for developing students' argumentation skills about socioscientific issues in high school genetics. *Research in Science Education*, 40(2), 133-148.
- Dawson, V.M., & Venville, G. (2009). High school students' informal reasoning and argumentation about biotechnology: An indicator of scientific literacy? *International Journal of Science Education*, 31(11), 1421-1445.
- Driver, R. Newton, P., & Osborne, J. (2000). Establishing the norms of scientific argumentation in classrooms. *Science Education*, 84(3), 287-312.
- Osborne, J., Erduran, S., & Simon, S. (2004b). Enhancing the quality of argumentation in school science. *Journal of Research in Science Teaching*, 41(10), 994-1020.
- Sadler, T. D., & Fowler, S. R. (2006). A threshold model of content knowledge transfer for socioscientific argumentation. *Science Education*, 90, (6), 986-1004.
- Sadler, T.D., & Zeidler, D.L. (2005a). Patterns of informal reasoning in the context of socioscientific decision-making. *Journal of Research in Science Teaching*, 42(1), 112-138.
- Sadler, T.D., & Zeidler, D.L. (2005b). The significance of content knowledge for informal reasoning regarding socioscientific issues: Applying genetics knowledge to genetic engineering issues. *Science Education*, 89(1), 71-93.
- Sadler, T.D. (2004). Informal reasoning regarding socioscientific issues: A critical review of research. *Journal of Research in Science Teaching*, 41(5), 513-536.

Simon, S., Erduran, S., & Osborne, J. (2006). Learning to teach argumentation: Research and development in the science classroom. *International Journal of Science Education*, 28,(2-3), 235-260.

Toulmin, S. (1958). *The uses of argument*. Cambridge, England: Cambridge University Press.

APPENDIX A

A Sydney IVF clinic has recently been offering to produce 'designer babies' for parents. For just \$10,000 the clinic will check and, if necessary, change the parents' genes in order to produce the baby of their choice. Once selected, the baby develops normally inside the mother. The choice at the moment is limited to sex, intelligence, height and hair colour but a spokesperson said that several other features would soon be available. All 'designer babies' are guaranteed free from identifiable genetic diseases.

Do you think this use of gene technology should be allowed?

Write as many reasons as you can to support your answer.