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Title: Teaching strategies for developing students' argumentation skills about socioscientific issues in high school genetics

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Abstract: An outcome of science education is that young people have the understandings and skills to participate in public debate and make informed decisions about science issues that influence their lives. Toulmin's argumentation skills are emerging as an effective strategy to enhance the quality of evidence based decision making in science classrooms. In this case study, an Australian science teacher participated in a one-on one professional learning session on argumentation before explicitly teaching argumentation skills to two year 10 classes studying genetics. Over two lessons, the teacher used whole class discussion and writing frames of two socioscientific issues. An analysis of classroom observation field notes, audiotaped lesson transcripts, writing frames and student interviews indicate that the teacher promoted quality argumentation by encouraging debate and listening, defining and exemplifying argument, prompting for justification of evidence, playing devil's advocate and encouraging reflection.

The implications for future professional learning and research are that the use of whole class discussion and writing frames of socioscientific issues in context promote argumentation skills.

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5 **Teaching strategies for developing students’ argumentation skills about socioscientific**
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7 **issues in high school genetics**
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11 **Introduction**
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16 Throughout our lives we are faced with a myriad of problems, dilemmas and conundrums
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18 about which we need to make decisions and choices. In our modern society, many of these
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20 issues centre around the products of science and technology. One of the essential outcomes
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22 of school science education is to enable students to use their understanding of science to
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24 contribute to public debate and make informed and balanced decisions about socioscientific
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26 issues that impact on their lives. Socioscientific issues are those that are “based on scientific
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28 concepts or problems, controversial in nature, discussed in public outlets and frequently
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30 subject to political and social influences” (Sadler & Zeidler, 2005, p.113). Young people are
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32 faced with personal choices about issues such as whether to not to use a mobile phone, eat
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34 genetically modified foods or recycle our household waste. As a society we make decisions
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36 about how to address global warming, soil salinity, population control and water supply and
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38 quality. The choices are not simple. Individuals need to be able to weigh up the risks and
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40 benefits, pose questions, evaluate the integrity of information and make decisions.
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48 Driver, Newton and Osborne (2000) suggest that a central component of science education
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50 that will help students make decisions, now and in the future, is that of argumentation. Kuhn
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52 (1991) defines an argument as “an assertion with accompanying justification” (p.12). Toulmin
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54 (1958) developed a model of argumentation which outlines the ‘parts’ of an argument and can
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56 be used both to teach students (and their teachers) the skills of argumentation and also to
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58 analyse or evaluate students’ argumentation. The main components of Toulmin’s
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4 argumentation model are *claims* (the conclusion, proposition or assertion), *data*, (the evidence
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6 that supports the claim), *warrants*, (an explanation of the relationship between the claim and
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8 the data), *backings* (basic assumptions to support the warrants), *qualifiers* (conditions under
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10 which claim is true) and *rebuttals* (statements which refute alternative or opposing claims,
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12 data and warrants) (Osborne, Erduran & Simon, 2004a).
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17 As far as the authors are aware, there is no published research on the use of argumentation in
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19 Australian science classrooms. In the UK, Osborne et al. (2004a) reported on a study of the
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21 design, implementation and evaluation of argumentation skills (using Toulmin's model) in
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23 high school science education. After providing continuous professional development and
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25 teaching resources to a group of 12 junior high school science teachers, the teachers
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27 integrated argumentation into their teaching. The authors collected video and audiotapes of
28
29 how the teachers developed argumentation skills and the subsequent students' discussion in
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31 small groups. The quality of students' argumentation was determined by examining the
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33 transcripts for instances of claims, data, warrants, backings and rebuttals. Levels 1 to 5 were
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35 assigned to each argument depending on the quality of the argument.
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42 The authors found that there was an improvement in the quality of students' argumentation,
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44 but it was not significant when compared to comparison groups. Rather, the quality of
45
46 students' argumentation was more related to the extent to which the teacher provided
47
48 opportunities for argumentation. Nevertheless, the authors were heartened as they recognised
49
50 that developing argumentation skills would take an extended period of time and other studies
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52 do show that "improvement at argumentation is possible if it is explicitly addressed and
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54 taught" (Osborne et al. 2004a, p. 1015). They also found that it was harder to implement
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56 argumentation in a scientific context than a socioscientific context.
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6 In Simon, Erduran and Osborne (2006) the authors' focus was on the argumentation dialogue
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8 used by those teachers whose students either did or did not exhibit a change in their level of
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10 argumentation skills during a lesson on a socioscientific issue one year apart. They found that
11
12 changes in students' argumentation skills could be linked to teachers' practice and that most
13
14 change occurred in classes where teachers focussed on helping students understand the
15
16 importance of talking, listening and reflecting, taking a position and justifying it with
17
18 evidence, constructing arguments and counterarguments and where the teachers modelled
19
20 argumentation skills themselves. The role of the teacher in encouraging reflection and
21
22 developing counter-arguments seemed particularly important.
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29 The crucial role of the teacher was also emphasised in a study by Jimenez-Aleixandre,
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31 Rodriguez and Duschl (2001) when they examined the audiotapes of group and class
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33 discussions of 15 year old students who were arguing about reasons for the yellow colour of
34
35 farm chickens in a genetics topic. They concluded that where the teacher "created a climate
36
37 of confidence which encouraged students to express and defend their opinions, combined with
38
39 the use of tasks that required students to work collaboratively and solve problems" (p. 782)
40
41 there was some argumentation exhibited.
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47 Zohar and Nemet (2002) reported on a case study of year 9 (15 year old) students from two
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49 schools in Israel who were taught a 12 hour unit on genetics that integrated explicit
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51 argumentation skills. The aims of the unit were to develop students' understanding of genetic
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53 topics (e.g., genetic counselling, inheritance, gene therapy and genetic cloning) and develop
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55 argumentation skills (e.g., developing and justifying arguments and counter arguments). The
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57 experimental group of 99 students were taught argumentation skills, bioethical principles and
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4 practised using these skills, while debating 10 moral dilemmas. When they were compared to
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6 a comparison group of 87 students who were taught a traditional genetics topic, the
7
8 experimental students were more likely to use their biological knowledge to improve the
9
10 quality of their arguments about bioethical dilemmas AND they scored significantly higher
11
12 (using a t-test) in a genetics test of 20 multiple choice questions. The authors concluded that
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14 teaching of explicit argumentation skills enhances performance in both conceptual
15
16 understanding and argumentation.
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22 In a recent study of the quality of argument expressed by Australian high school students
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24 (aged 12 -17 years) who were interviewed about gene technology processes it was found that
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26 about three quarters expressed low level arguments consisting of either claims only or claims
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28 and data (Author, 2006). Warrants, backings and qualifiers were not present. The findings
29
30 were consistent across three age ranges from 12-17 years old. In addition, less than 20% used
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32 rational informal reasoning to justify their claims (Sadler & Zeidler, 2005). They tended to
33
34 use emotive and intuitive informal reasoning.
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40 The aim of this research was to identify the types of strategies used by an Australian high
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42 school science teacher as he introduced argumentation skills to his year 10 science class. The
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44 research questions were:
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- 49 1. Following a professional learning session on argumentation, what strategies did the
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51 teacher use to promote argumentation?
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- 54 2. What were the students' perceptions of the degree and quality of argumentation in the
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56 post professional learning classes?
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Research Method

The research presented in this paper is part of a larger study to examine the effect of explicit instruction in argumentation on year 10 students' conceptual understanding of genetics and their decision-making about socioscientific issues in a genetics context. Year 10 students (14-15 years) were chosen as the research sample because genetics is typically taught in year 10 in Australian schools. After year 10, science is no longer a compulsory subject and only one third of students continue with biology.

An instrumental case study approach (Stake, 2000) was the primary research method. It is intended that the findings of this case study, which is exploratory will inform the design of further research and professional development on argumentation. For the research presented here, data was generated through semi-structured pre and post unit student interviews (n=12), teacher interviews, students' work samples, field notes of a professional learning session on argumentation, classroom observations and audiotaped lesson transcripts. The use of these multiple sources of data allowed triangulation and cross-checking of emergent hypotheses.

Sample

The research site was a metropolitan Catholic co-educational high school with 960 students in Years 8 to 12. The school is located in a middle class suburb of Perth, Western Australia. The science department is well resourced with a full time laboratory technician, computer support and access to a wide range of laboratory equipment. Most of the staff are experienced teachers who regularly participate in science professional development. The research was

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4 conducted with Mr D, a well regarded biology teacher with 19 years experience and his two
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6 year 10 classes of 46 students.
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10 Mr D participated in a one-on one professional learning session on argumentation before
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12 explicitly teaching argumentation skills over two lessons to the two Year 10 classes.
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14 Extensive field notes were recorded by both authors during the professional learning session
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16 and the lessons on argumentation. Audiotapes of the lessons were transcribed. The transcript
17
18 sections of teacher talk related to argumentation were coded using the framework developed
19
20 by Simon et al. (2006). In this framework, the methods or strategies used by teachers who
21
22 were effective in promoting argumentation were identified. (See the first two columns of table
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24 1 in the results section.)
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31 A sample of 12 students from each of Mr Ds two classes were interviewed before studying a
32
33 10 week genetics topic. Ten of these students were re-interviewed after the topic. They were
34
35 asked questions about their understanding of genetics concepts and their decision-making
36
37 about two genetics dilemmas. The students were selected by Mr D using a purposive
38
39 sampling method (Patton, 1990) that allowed for a range of academic abilities. The classes at
40
41 this school were not streamed for academic ability and the interviewed students were
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43 identified by the teacher as being of high, medium and low academic science ability. In
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45 addition to questions about genetics, in the post unit interview, the students were asked what
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47 they thought of the argumentation lessons. The interviews were transcribed and the transcript
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49 sections on students' perceptions of argumentation were analysed for emergent themes.
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56 **Results**

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4 ***Professional learning session***
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8 In July, 2006, Mr D agreed to trial argumentation skills with his two year 10 classes. Mr D
9 was given an information paper written by the authors which summarised the principles of
10 argumentation and how it could contribute to conceptual understanding and scientific literacy.
11
12 Mr D then participated in a 90 minute one-on-one professional learning (PL) session using the
13
14 UK produced *Ideas, evidence and argument in science* (IDEAS) materials (Osborne, Erduan
15 and Simon, 2004b). Mr D viewed video excerpts from IDEAS and was introduced to
16
17 Toulmin’s model of argument, examples of arguments and their parts (i.e., data, claim,
18
19 warrant, backing, qualifier and rebuttal) and the use of argument prompts. The benefit of
20
21 using argument in decision-making was also discussed. The professional learning session
22
23 was conducted as an interactive discussion with Mr D having significant input as he discussed
24
25 his ideas on how best to teach argumentation. Mr D was offered a choice of three
26
27 socioscientific issues set in a genetics context that could be used to promote argumentation.
28
29 The three issues had been used previously with year 10 students. He chose one based on
30
31 cystic fibrosis (Author, 2000) and the other on genetically modified tomatoes (Lewis, 2000)
32
33 as he believed they best suited the genetics content that the students had recently been taught.
34
35 Mr D also suggested the use of a writing frame with guiding questions to scaffold students’
36
37 thinking. Writing frames have been shown to enhance thinking and writing skills in science
38
39 (Hand, Wallace, & Yang, 2004). See Appendix A for a copy of the writing frames with the
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41 socioscientific issues and guiding questions. Note that in the version used by students, space
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43 was allowed for students to write their responses.
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56 ***The lessons***
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4 Mr D's class was observed prior to the argumentation lessons to ascertain his teaching style.

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6 Mr D was a very confident teacher who encouraged independent learning in his students. He
7
8 wanted them to take responsibility for their learning. Typically, the students worked
9
10 independently in small groups, with Mr D calling the class together at intervals to check on
11
12 progress and provide information. As students worked he circulated from group to group.
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15 There was a hum of noise in the class and students were largely on task.
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20 Mr D taught argumentation skills to his two Year 10 classes over two consecutive lessons of
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22 100 minutes. Both classes were approaching the end of a 10-week genetics topic which
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24 covered reproduction, inheritance, Mendelian genetics, human genetic diseases, genetic
25
26 engineering and genetic screening for single gene disorders.
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31 The structure of the lessons were as follows. After reviewing the previous lesson, Mr D
32
33 explained to students that they were going to learn about some strategies for decision-making.
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35 On the white board was a diagram of a tomato with the words, data, claim, warrant, backings
36
37 and rebuttal inside it. Mr D explained what each of the words meant in relation to
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39 argumentation and then handed out the writing frame for the genetically modified tomato
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41 issue. Students were asked to read about the socioscientific issue by themselves and write
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43 down what they would do. Without discussion, they were instructed to answer the first two
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45 questions where they were asked what further information they needed and to write evidence
46
47 to support their decision. Mr D then led a whole class discussion interspersed with periods
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49 when the students used the writing frames. Students were asked to consider the benefits and
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51 risks of their decision and how they would convince someone who disagreed with them.
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54 After the discussion, students answered the final question about whether or not they had
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56 changed their decision. Mr D then repeated the same process with the cystic fibrosis issue.
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6 Several features of Mr Ds discussion strategies were recorded in the field notes:
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10 Mr D uses students' names whenever they respond to, or ask a question, calls on all
11 students, rephrases or restates answers so the whole class can hear, builds on students'
12 responses by adding more information and then posing a more difficult question or
13 moving the discussion to the next point. He encourages students to answer each others'
14 questions with himself as the intermediary. He uses humour and listens actively. He
15 acknowledges students' responses with "that's good" before building on an answer. He
16 prompts responses by providing hints. Students appear to be aware of the 'rules' of
17 discussion and several students were reminded that they could only ask or answer four
18 questions in a single lesson so that other students could participate. (Field notes, 3/8/06)
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33 In order to examine more closely the strategies used by Mr D to promote argumentation, the
34 audiotaped lesson transcripts were analysed using the framework developed by Simon et al.
35 (2006). Table 1 summarises, and provides exemplars from the lesson transcripts of the
36 behaviours exhibited by Mr D. All behaviours were demonstrated on at least one occasion.
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45 Insert table 1 about here
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50 Despite a brief professional learning session, Mr D used all of the methods to facilitate
51 argument that were identified by Simon et al. (2006) in UK teachers who were effective in
52 developing students' argumentation skills. In the discussion we propose several possible
53 explanations as to how Mr D after a brief professional learning session was able to exhibit
54 these behaviours, and the implications for future professional learning on argumentation.
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6 *Students' perceptions*
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10 During the argumentation lessons, we observed that the students were engaged and on task.
11 They appeared to enjoy expressing their views about the two socioscientific issues. The
12 students listened to each other and did not tend to talk over or interrupt each other, partly as a
13 result of Mr D managing the discussion. Apart from when students were using the writing
14 frames, there was a constant dialogue of student-student and student-teacher talk about the
15 issues.
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26 Two weeks after the argumentation lessons, ten of the students from the two classes were
27 interviewed. The students were each asked to describe their recollections of the socioscientific
28 issues. They were asked what they thought of the lesson and what Mr D did to help them
29 make a decision. All of the students vividly recalled the two socioscientific issues and
30 initially responded by describing the two socioscientific issues and outlining their views.
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40 When asked what they thought of the lessons, the students were unanimous in stating that
41 they enjoyed the lessons especially the whole class discussions.
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47 Yeah, I thought it was quite fun because I was alright at it and, yeah, it was fun just
48 discussing stuff, like I didn't do a heap of writing. Yeah, I didn't find it too hard or
49 anything like that. It was easy to cope with. (J, 17/8/06)
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4 I did enjoy it because it was different than just telling the facts and the way Mr D did it,
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6 he asked everybody, we did the sheet first, just the first page of it and that was just
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8 making up your mind (C, 17/8/06)
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12 I enjoyed it because of the whole class discussion (R, 17/8/06)
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16
17 Many of the students identified the methods used by Mr D in facilitating argument through
18
19 the whole class discussion. They included providing information to support or rebut their
20
21 claims, building on their answers by providing more data, asking prompt questions of many
22
23 students to draw out backings and qualifiers and enabling the expression of many views
24
25 (claims and counter claims). For example:
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31 If we gave a reason he'd kind of expand on that and he like helped us understand – lot's
32
33 of people were confused about a few things (R, 17/8/06)
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38 He gave us some scenarios and inside the scenario he'd say like, what if this happened?
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40 And then what about if you put this and this and then what would happen? (J, 17/8/06)
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45 It was good how we like, yeah, everyone had their own input. (R, 17/8/06)
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49 The students valued listening to the arguments (counter claims and rebuttals) put forward by
50
51 their peers. For example:
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56 I learnt that like there are lots of different opinions and it's kind of good how everyone
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58 has their own input - that's what I liked about it and like yeah, there was lots of
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4 different opinions which can twist the way you look at it and some were good and some
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6 were bad. (R, 17/8/06)
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11 I thought the lesson was good because we all got to discuss and we all like heard
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13 different opinions from other people and we all thought about it. (S2, 17/8/06)
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18 The students not only listened to, but were influenced by the evidence put forward by their
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20 peers.
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25 Everyone has their own opinions on certain topics and it kind of changes the way you
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27 think about the topic when you hear other people's opinions so you might be for it and
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29 when you hear certain things you might be against it. (S1, 17/8/06)
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34 We kind of had a light debate about it – like we'd all give our own opinion and then he
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36 was like it's OK if you change your mind, like if you started off thinking one thing and
37
38 then changed it, like that's fine but we all like gave our opinions and then we kind of
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40 thought outside the box and how they would feel and how the father would feel and ...
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42 it kind of bought ideas to your head but then you still had ours – you kind of, you're
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44 fighting with yourself on which one to choose . (V, 17/8/06)
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50 Most students recognised the benefits of a whole class discussion where evidence was used to
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52 support claims. For example:
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57 We built off each other's ideas and came up with more ideas than we would have done
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59 by ourselves and learnt more about the cystic fibrosis one, DNA testing and with the
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4 Flavr Savr one all about how it could be different with climate conditions... It left it up
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6 to us to think and then by using our ideas and some of the things Mr D said and
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8 everybody else, we were able to understand more of the different effects and
9
10 everything. (Ca, 17/8/06)
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15 **Conclusion**

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20 In this study, an experienced biology teacher introduced his year 10 students to argumentation
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22 skills during a genetics topic as they examined two socioscientific issues, one on a genetically
23
24 modified tomato and the other on prenatal genetic screening for cystic fibrosis. Based on
25
26 classroom observations, analysis of the lesson transcripts and student interviews we conclude
27
28 that the impact of introducing argumentation was influenced by four factors. They were the
29
30 role of the teacher in facilitating whole class discussion, the use of the writing frames, the
31
32 context of the socioscientific issue and the role of the students in this classroom.
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38 The two main teaching strategies used by the teacher were whole class discussion led by the
39
40 teacher and individual student writing frames. An advantage of whole class discussion was
41
42 that the teacher could control and monitor all student input, ensure that students were on task
43
44 and direct argument strategies to the whole class. Also, unlike writing frames where students
45
46 were working individually, they were able to articulate their views and listen to rebuttals,
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48 warrants, backing, qualifiers and data that they may not have been aware of.
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54 Research from the UK has shown that a lack of teacher expertise in facilitating discussions
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56 may inhibit students' ability and opportunity to engage in argumentation (Oulton, Dillon and
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58 Grace, 2004). Similarly, Bryce (2004), after interviews with 41 Scottish biology teachers
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4 found that they were reluctant to consider social and ethical aspects of controversial issues
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6 because they felt that they did not have the skills to effectively use discussion. In contrast, Mr
7
8 D had no difficulty using whole class discussion with his students. Both authors are
9
10 experienced science education researchers and have conducted numerous classroom
11
12 observations. After observing Mr D teach, both of us agreed that Mr D was an exemplary
13
14 biology teacher. During the pre-argumentation lesson classroom observations we noted that
15
16 Mr D was highly accomplished at facilitating discussion and that he frequently employed that
17
18 strategy. As a result, the students also understood their roles which were to listen to the
19
20 teacher and their peers, answer and ask questions, and share their understandings and views.
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27 The whole class discussion was interspersed with periods when students wrote their answers
28
29 to questions from the writing frames. The questions were designed to act as argument prompts
30
31 to encourage students to make a decision and to articulate reasons for their decision. The use
32
33 of writing frames enabled students to work and think individually without input from their
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35 peers. The nature of the questions (e.g., ‘how would you convince someone who disagreed
36
37 with you?’ encouraged students to use data, warrants and make explicit the underlying
38
39 assumptions (backings) that supported their claims.
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46 Another feature of this lesson is that the teacher used socioscientific issues that were set in a
47
48 genetics context so that students were able to readily apply their newly acquired knowledge.
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50 This is similar to the successful use of bioethical dilemmas to promote argumentation used by
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52 Zohar and Nemet (2002). Despite, not being familiar with the specific issues, Mr D was able
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54 to draw on his broad biology background knowledge and awareness of students’ prior
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56 knowledge. This enabled him to provide content knowledge and prompt students’ when
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6 The beliefs and skills of the students need to be considered in developing their argumentation
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8 skills in science. If students are unaccustomed to questioning scientific knowledge, evidence
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10 or the teacher, they may be reluctant to engage in argumentation. In the two classes observed,
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12 the students seemed very comfortable with providing their point of view and were also
13
14 willing to listen to the teacher and their peers.
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20 Simon et al. (2006) claim that teachers' underlying beliefs and skills prior to professional
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22 learning are crucial in their ability to develop students' argumentation skills.
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24 Overall, this study does seem to demonstrate that for this experienced biology teacher, a brief
25
26 professional learning session on argumentation was sufficient for him to develop the skills to
27
28 introduce his students to argumentation. Thus, it is recommended that professional learning
29
30 activities may need to be tailored to teachers depending on their genetics content knowledge,
31
32 experience with whole class discussion, prior teaching of socioscientific issues and familiarity
33
34 with argumentation skills. If teachers are inexperienced or unfamiliar with any or all of these
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36 aspects, then they may need an extended period of time to practice whole class discussion
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38 with their students using familiar topics before introducing argumentation skills.
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46 47 **Appendix Writing Frames on Socioscientific Issues** 48 49

50 51 52 The Flavr Savr Tomato 53 54 55

56 Today, the Flavr Savr tomato went on sale in the USA for the first time. Normal tomatoes rot
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58 quickly once ripe. To overcome this, producers pick them when they are green and allow
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4 them to ripen during shipping and storage. Many people complain that this makes the tomato
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6 tasteless.
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10 The Flavr Savr tomato has been genetically altered to prevent it from rotting as quickly as
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12 normal tomatoes. It can be picked once ripe and will not rot during transport or storage.
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14 Producers claim that this makes the Flavr savr tomato taste better.
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17 *Should the Flavr Savr tomato be grown and sold in Australia?*
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22 Yes _____
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26 I don't know _____
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31 No _____
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38 **Questions**

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42 What further information would help in making your decision?
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45 What evidence supports your answer?
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47 What are the possible benefits or advantages of your response?
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49 What are the possible risks or disadvantages of your response?
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51 Are there other reasons for why your claim is true?
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53 Under what conditions is your claim true?
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56 If someone disagreed with you how could you convince them that your answer is the best?
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58 Has your original decision changed? In what way?
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6 Cystic fibrosis
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10 Mr. and Mrs. C come to a genetics clinic for prenatal diagnosis. They have each been tested
11 to determine whether they carry the gene for cystic fibrosis, a hereditary lung disease that
12 causes severe breathing problems. The cystic fibrosis gene is recessive, so a child must
13 inherit a copy from each parent to get the disease. In this case, both Mr. and Mrs. C are
14 carriers for the cystic fibrosis gene. The specific mutations for each parent were identified in
15 earlier tests.
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26 Mrs. C, who is pregnant, undergoes prenatal diagnosis to determine if the foetus is affected.
27 DNA analysis indicates that the foetus does have two copies of the cystic fibrosis gene, but
28 one of the mutations it carries is different from that of either Mr. or Mrs. C. That makes it
29 virtually certain that Mr. C is not the baby's father.
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38 If you were the genetics counselor would you tell **BOTH** Mr and Mrs C the test results?
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Table 1 Examples of argumentation processes exemplified by the teacher

Argument process	Codes for teacher facilitation	Example from transcript
Talking and listening	Encourages discussion	<p>p. 6 So you're saying that everybody on this planet is so ethically and morally perfect nobody will do the wrong thing?</p> <p>p.3 What was your first initial response to the business about the Flav'r Sav'r tomato?</p>
	Encourages listening	p.4 Oh that's good Steph. Yes, so Steph's also making that comparison.
Knowing meaning of argument	Defines argument	p.3 So with the tomato, you've got a claim and a counter claim.
	Exemplifies argument	p.9 So it's a bit like saying, man never landed on the moon, or man landed on the moon, and the counter claim is, of course, no he didn't, you look at the flag, there's no way they could have done it. So we've got a claim and a counter claim.
	Encourages ideas	p.14 Good, Bryce is thinking out various scenarios in his head. I think that's always good.
	Encourages positioning	p.11 If you were the genetics counsellor, would you tell both Mr and Mrs C the test results?
	Values different positions	But I think that sometimes we need that, we need people to stand up and give us that other point of view.
Justifying with evidence	Checks evidence	They've actually given you that word, Danielle, what is that word? (Danielle – mutation)
	Provides evidence	p.7 The hostesses or stewards will walk up and down the isle and they'll say please fill out these

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		quarantine cards and watch the video.
	Prompts justification	p. 11 Teacher – Now because it’s recessive if you have just one of them, can you get the disease? (S – No) Teacher – No, so we’re drawing back on the work we did in genetics.
	Emphasizes justification	p. 10 Teacher – What do I need more of? (S- Evidence) Teacher – More evidence. So like I need more data.
	Encourages further justification	p. 6 Once again another example of where we need a bit more research, a bit more data so we can back up some comments.
	Plays devil’s advocate	p. 13 What if you were the father, would you want to know?
Constructing arguments	Uses writing frame or written work/prepares presentations/gives roles	p. 2 I’m going to hand out a sheet to you. Have a bit of a read first and as you are reading it be critical.
Evaluating arguments	Encourages evaluation	p. 2 You know when you read something you should be a little bit critical.
	Evaluates arguments process – using evidence/content – nature of evidence	p. 8 ... how would you try and convince that your claim, or the way that you thought about a problem, how would you try to convince other people?
Counter-arguing/debating	Encourages anticipating counter-argument	p. 6 And then we’ve got people who are willing to, and we discussed this one the other day too, you know there is going to be a bit of a rebuttal there to. What are we going to qualify?
	Encourages debate (through role play)	p.11 If you were the genetics counsellor, would you tell both Mr and Mrs C the test results? p. 13 What if you were the father, would you want to know?

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Reflecting on argument process	Encourages reflection	p. 10 That's a really good point. Do you think that's what schools are trying to do with their science programs though? Is there any way that a school with maybe one lesson of science a day, is going to bring you fully up to speed with what's happening in the science world? ... So we're not actually asking you to remember absolutely everything. Perhaps we are asking you to remember certain techniques, like we're doing now. We're talking about how to create a constructive argument.
	Asks about mind-change	p. 9 Okay, hand up those people who have changed their mind between the start of the that sheet and Who heard what somebody else said and maybe changed their mind on it?

Title

Teaching strategies for developing students' argumentation skills about socioscientific issues in high school genetics

Running head

Argumentation and socioscientific issues in genetics education

Keywords

Argumentation, genetics education, socioscientific issues

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Abstract

An outcome of science education is that young people have the understandings and skills to participate in public debate and make informed decisions about science issues that influence their lives. Toulmin's argumentation skills are emerging as an effective strategy to enhance the quality of evidence based decision making in science classrooms. In this case study, an Australian science teacher participated in a one-on-one professional learning session on argumentation before explicitly teaching argumentation skills to two year 10 classes studying genetics. Over two lessons, the teacher used whole class discussion and writing frames of two socioscientific issues. An analysis of classroom observation field notes, audiotaped lesson transcripts, writing frames and student interviews indicate that the teacher promoted quality argumentation by encouraging debate and listening, defining and exemplifying argument, prompting for justification of evidence, playing devil's advocate and encouraging reflection.

The implications for future professional learning and research are that the use of whole class discussion and writing frames of socioscientific issues in context promote argumentation skills.

