

SUPPORTING TEACHERS, CHALLENGING STUDENTS: SOCIALLY RESPONSIBLE SCIENCE FOR CRITICAL SCIENTIFIC LITERACY

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ABSTRACT

This paper presents the results of research into a nationally funded project, 'Socially Responsible Science', in which science teachers developed and implemented *ethical dilemma story pedagogy* in their own classrooms. The research focused on (i) science teachers' success in creating a values learning classroom environment and (ii) the impact on student learning, in particular their development of collaborative problem solving, evidence-based decision making, critical thinking and critical reflection. The research methodology consisted of ethnographic participant classroom observations and interviewing as well as the implementation of a specifically designed questionnaire - the Values Learning Environment Survey (VLES) – to obtain measures of students' perceptions of key aspects of their learning activities. The research results identify key factors shaping teachers' differential design and implementation of dilemma story pedagogy and students' differential engagement in values learning.

Keywords: *socially responsible science education; dilemma story pedagogy; values learning; scientific literacy.*

INTRODUCTION

In this paper we present the results of research into a nationally funded project, 'Socially Responsible Science (SRS)', designed to enable science teachers to better prepare young people for our crisis-ridden world by developing their critical scientific literacy skills. As Hodson (2008) explains, there is growing interest in a 'universal critical scientific literacy' that equips all students with "the capacity and commitment to take appropriate, responsible and effective action on matters of social, economic, environmental and moral-ethical concern" (p. 2). As facilitators of the project we drew on our commitment to a transformative science education that better prepares students to participate as informed members of society and future decision-makers in the science-informed discourse about pressing global issues such as climate change and environmental sustainability. We drew also on our earlier research, based on the pedagogical use of stories for moral development (Vitz, 1990), that had demonstrated the efficacy of *ethical dilemma story pedagogy* for engaging students in values learning in the science classroom. In that study teachers had used specially prepared ethical dilemma stories to engage students in critical reflective discourse and collaborative decision-making on the ethical implications of science and its uses (Settelmaier, 2003, 2009). This innovative approach to socially responsible science education addresses the National Framework for Values Education in Australian Schools and the National Goals for Schooling in the Twenty-First Century, as outlined in the Adelaide Declaration (1999), which argue that Australia's future depends on a solid foundation for young Australians' intellectual, physical, social, moral, spiritual and aesthetic development (Department of Education, Science & Training, 2005). This approach also contributes to the recent call to 're-imagine' science education as an exciting, authentic, investigative and meaningful experience for all students (Tytler, 2007). In this respect, a good ethical dilemma teaching story – like all classic moral dilemmas - has no final solution, thus allowing for prolonged thinking, reflection and learning. Content knowledge – chemistry, biology, physics, mathematics concepts and skills - is essential in order to understand and to find solutions to the ethical dilemmas embedded in the stories. Thus dilemma story pedagogy does not aim at replacing content-based science education but rather aims to enhance its quality and relevance to modern day students by 'adding value' to their learning. During the project, science teachers participated in

professional development workshops designed to familiarise them with ethical dilemma story pedagogy and to write ethical dilemma stories relevant to their specific curriculum contexts, to their students, and to local community issues and concerns. The ethical dilemma stories, together with project teachers' implementation notes, are available to science teachers worldwide on the project website: www.dilemmas.net.au. This paper focuses on selected teachers' implementation of ethical dilemma stories in their science classes.

METHODOLOGY

Our research into the teachers' classroom implementation of their ethical dilemma teaching stories was shaped by a multi-paradigmatic research design perspective (Taylor, Settelmaier & Luitel, in press). We employed a mixed-methods approach which included (a) ethnographic methods of participant observation and interviewing and (b) administration of the Values Learning Environment Survey (VLES). The original participants included 8 metropolitan government secondary schools, 22 science teachers, 65 secondary students in Years 9-12 and 17 postgraduate students. This paper focuses on four of the teachers - two female and two male. The research received ethics clearance by the Curtin University Ethics Committee. Participants' identities and schools' names are protected through the use of pseudonyms.

Ethnographic Component of the Research

The ethnographic component of the study involved participant observation of classroom teaching and interviewing of teachers and students. This part of the study formed the basis for the third author's Bachelor of Education Honours thesis. As a research assistant, Julia spent an extended period of time at each school observing classes conducted by the participating teachers. Elisabeth observed all but one of the four teachers' classes. Julia interviewed five students per class and the class teacher and collected the completed questionnaires after they had been administered by the teachers. Students were chosen for interview on the basis of their involvement (or lack thereof) during class and their gender. The quality standards governing this part of the study were trustworthiness, transferability, credibility and fairness (Guba & Lincoln, 2005). Fairness of representation was established through member checking and giving 'voice' to participants as often as possible.

The Values Learning Environment Survey (VLES)

The quantitative component followed standard learning environment research procedure for optimising reliability and validity (Taylor, Fraser & Fisher, 1997). The VLES questionnaire was administered by the teachers shortly after each dilemma teaching episode, yielding 65 useable student responses. The instrument can be accessed on the project website. The VLES was developed with three specific goals: (a) to promote values learning: the instrument provides teachers of science (and other school subjects) with a clearly articulated framework for establishing a values learning classroom environment; (b) to assess values learning: the instrument provides teachers with a relatively simple method for assessing the quality of students' engagement in values learning; and (c) to monitor values learning: the instrument allows teachers and researchers to trace students' long-term values learning development. We designed the VLES in order to obtain measures of students' and teachers' perceptions of 6 key factors of the classroom learning environment that our earlier research shows (Settelmaier, 2009) are conducive to values learning: *critical self-reflection*, *empathic communication*, *critical social thinking*, *deep engagement*, *collaborative decision-making*, *teacher support*. Each of these factors became initially a 7-item scale, later reduced to five. We designed the questionnaire in two versions for measuring perceptions of the learning environment as experienced (a) by students and (b) by teachers. Previous research has established that student achievement is optimal when students perceive a close match between their preferred and actual learning environments (Fraser & Fisher, 1983). We incorporated a five-point Likert-type frequency response scale. For readability purposes on the questionnaire we re-named the scales: 'The Dilemma Story' (*deep engagement*); 'The Teacher' (*teacher support*); 'Learning to Work Together' (*collaborative decision-making*); 'Learning to Listen' (*empathic communication*); 'Learning to Think' (*critical self-reflection*); and 'Learning

about Science' (*critical social thinking*). Statistical analysis revealed that the Cronbach alpha coefficients lie in the range of 0.76-0.91, indicating satisfactory internal consistency of all scales.

RESULTS AND DISCUSSION

Our discussion of the results focuses on (a) the differential quality of the teachers' implementation of ethical dilemma story pedagogy in their science classes and (b) the impact on students' learning experiences.

Teachers as Facilitators – The Teachers' View

Here we focus on four teachers in three government senior high schools in metropolitan Perth who implemented dilemma story pedagogy in their classrooms. Both female teachers, Delia and June, taught at the same school, whilst the two male teachers, Jeremy and Ron, taught at different schools. Although they had attended the same professional development workshops, it was only the two female teachers who adhered closely to our intended dilemma story teaching approach: *to read out loud or tell freely a dilemma story to the whole class and to pause from time to time for individual student and small-group reflective learning activities*. This approach is designed to enable students to identify deeply with the main character in the story and to make decisions on behalf of the character. Delia dedicated several preceding lessons to teaching specific content to her Year 10 class in preparation for the *Western Swamp Tortoise Dilemma story* (see project website for details). June used the *Climate Change Dilemma story* with her Year 12 class as an introduction to a new topic. In contrast, Ron and Jeremy chose to implement dilemma teaching in a more didactic manner: without using a story-telling approach, they presented their classes with dilemma questions only and instructed students to work directly on the questions. Ron presented a dilemma scenario approach related to the topic of *Reproduction*. Jeremy provided his students with a range of loosely connected questions in relation to the topic of *Genetic Counselling*. Thus, dilemma story teaching was not implemented consistently across the sample.

During interviews both Jeremy and Ron seemed to assume that the SRS approach catered more for the teaching and learning of values education rather than for science education per se, as expressed in Ron's comment, "I would have thought it was much more values than science." June and Delia, on the other hand, expressed a view of science and values as being inseparable. In contrast, all of the interviewed students seemed to think that the focus of the ethical dilemma stories was science. Some seemed uncertain as to the concept of 'values' but most interviewed students reported they had been able to apply their science knowledge when trying to solve the dilemmas. Literature on values education (op cit) states that many teachers avoid engaging with values education as part of their curriculum since the curriculum is 'too crowded'.

We asked the four science teachers how they could see socially responsible science education fit into the mainstream science curriculum. Jeremy explained that it was easier to fit ethical dilemma stories "...into lower school classes rather than upper school classes." This was considered to be particularly the case for classes in which university aspirations were low which Jeremy assumed would be the case with his classes and his school. Ron seemed not convinced that this type of learning was 'legitimate science' and admitted that, "I probably wouldn't have done this if you weren't coming." We were surprised to hear this type of comment from somebody who had been involved voluntarily in the project from day 1 and who had attended all professional development workshops. One might wonder as to what motivated Ron to participate in the first place and to agree to participate in the research component of the project. Given his misgivings about the dilemma learning approach, he seemed genuinely surprised that, "...they [my students] were really engaged. They were much more engaged than they usually are!" Both male science teachers thus seemed to have doubts as to whether this type of learning was science and not just a 'waste of precious time'. This stands in stark contrast to their students' opinions as described later in the paper. While both the female teachers felt they would "...not be teaching the full curriculum if values were not taught in the science classroom" and seemed to feel that, "...ethical dilemma stories would be a useful strategy to achieve this". Delia expressed an interest in conducting an ethical dilemma story prior

to a unit of study and then conducting it again at the end of a unit of study to see how scientific knowledge helps students form their values. June described the "...values and science as inseparable". It is interesting to note that the two male teachers apparently thought that this approach catered more for the teaching and learning of values education, while the two female teachers I interviewed seemed to view science and values as inseparable.

Students' Deep Engagement with the Dilemma Learning Experience

Students' deep engagement with dilemma stories and the dilemma learning experience is crucial for the success of this type of pedagogy (Settelmaier, 2009). The results of the ethnographic aspect of the inquiry indicated that students' engagement with the dilemma stories seemed positive, and most interviewees described the experience as 'fun' and as 'different' from usual science classes. As Michaela pointed out, "I thought it was really good." Emma, Lee and Phil also seemed to enjoy the dilemma experience as fun and different: Emma contended that it was "...good to learn about how stuff works and there is more to it than just looking at it". Lee elaborated further that "...it kinda didn't feel like science ...but it was good to do something different." Phil described the experience further as, "... it was different from a regular class... 'cause normally it's book work kind of stuff. This was different as it wasn't really to do with the books, it was good." Peta, one of the top students in her class seemed to have been able to combine fun with the application of science knowledge, "...it really did help us apply what we have learned in science... and yes, I could use my science knowledge." Only one student reported not being interested in the topic of 'his' story: his class had been engaged in the *Western Swamp Tortoise Dilemma Story* and he was open about the fact that he wasn't interested since "turtles weren't down his alley". This also confirms one of the outcomes of Elisabeth's doctoral research which was that dilemma story topics must be relevant to the students: if students do not relate to or do not fully understand the dilemma in a story, they cannot engage in the necessary thinking and reflection processes. Students commented on the potential of the dilemma learning experiences to 'get people to think' and to 'wake them up'. Some students, like Sam, apparently experienced the dilemma learning experience as a 'wake-up call', "I know for a lot of people it did kind of ...umm ...wake them up as to who they would choose." Students, like Chloe, also pointed out the connection to real life, "...it could happen, you know, and you would have to face that dilemma." James seemingly referred to a similar 'link between the classroom and real life' when he stressed the importance of becoming aware of how others think and feel, "...if you don't know...you're not going to care. You're not going to know how that person feels." The link between knowing about others' thinking and feelings and caring about others was also explained by Leah who described the dilemma learning experiences as, "...it does teach people values because if you don't know then you don't really care how the other people think about it." Furthermore, students seemed to suggest that this type of learning be included more often in order to teach about the applicability of science to real life. Matt appeared to confirm the importance of using this type of learning repeatedly by saying, "...yes, [it would be good to do this again] because it makes you think about what you do because when I just learned this stuff it was really fresh in my head...just makes me learn the other stuff again and remember it....and use it in real situations". Matt's statement is supported by Peta who stated that, "...I think it should be done occasionally to help us understand how science is applied more in the real world.....in science, the way we learn it, we don't do as many stimulating activities [in relation] to how we'd apply it to the real world". Even Dan who said he didn't normally much enjoy science confirmed that, "...I think it (should be done) a few times."

Summarising, we can say that students' feedback regarding engagement with the dilemmas was generally positive: students commented on the potential of the dilemma stories to 'get people to think' and to 'wake them up', that it was fun and different from usual science classes. Furthermore, they pointed out the importance of the connection to real life. These qualitative findings are also confirmed by the results of the quantitative analysis whereby nearly two-thirds (65%) of the students indicated the dilemma stories were deeply engaging, relevant to their lives, felt curious about the stories, and were

keen to solve the problems in the stories. A third of the group was unsure, with one student disagreeing.

Teacher as Facilitator - The Students' View

The teacher's role as a facilitator, agent provocateur, or devil's advocate is vital within our values learning environment. The teacher is more of a guide than a 'dispenser of values'. Given that science teachers often find themselves in the role of the person who 'has all the knowledge', taking a step back and allowing students to engage actively in their values learning can be a challenge, as expressed by two of the participating teachers in their interviews. However, interviews and observations indicated that teachers seemed to receive mostly positive feedback on their facilitator role, their engagement with the students, and for trying something new and different. Student Leah noticed that apparently, "...he [the teacher] was not really comfortable with the new ways...but he did a good job." Whilst other students, such as Matt, confirmed that their teachers seem to act as facilitators most of the time, "...she always teaches us like that. This time it was just more so...!" Students, like Dan, seemed to appreciate the opportunity to speak up and be heard, "...[He] just listened ...[and]...[he] let us express our opinions without telling us we're wrong. Students also noted the unique opportunity for their teacher to learn about his/her students, something that apparently doesn't happen normally, as was expressed by Emma, "...because he has basically learned about us throughout the year but there's still some spots that were vague in our personalities that he knew and through this exercise he could really get a stronger vantage point of our character." It was interesting how important it seemed for students that their teacher knew something about them personally.

Summarising our qualitative findings we can say that teachers received positive student feedback on their facilitator role and their engagement with the students, and positive recognition for trying something new and different. Students also seemed to note a unique opportunity for their teachers to learn about them. Furthermore, students appeared to appreciate the opportunity to speak up and be heard without being interrupted or told off for talking. In addition, these results derived through the ethnographic component of the study have been confirmed by the quantitative results where nearly all (94%) of the students indicated that their teachers facilitated their engagement in dilemma story learning activities by stimulating their thinking, encouraging them to participate and accepting the views of others. Only a very small proportion was unsure and none disagreed.

Collaborative Problem Solving and Evidence-Based Decision-Making

Collaborative decision making involves student groups negotiating a decision and/or a compromise in order to solve a problem as a group. Furthermore, students draw on both their own values and increasingly on evidence provided to them through their science learning to make informed decisions. One of the key issues raised during the ethnographic inquiry was the importance of recognising difference in opinions and values and working with it. Students reported that through the group-work and the discussions they seemed to become more aware of different opinions. For some this didn't seem to cause any problems since, as Vicki put it, "I'm used to people having different opinions." Some students, on the other hand, reported difficulties in the decision-making process due to conflict which may or not have been resolved, like in Julie's group's case, "... there was a little bit of conflict in my group!" I think they both just let it go 'cause they knew they weren't going to change either one's idea. So they decided to just stick with their own [opinion]." It appeared that students in her group rather compromised than tried to convince the other person. Students also indicated that knowing about each other's different opinions did not necessarily cause them to change their own. "After I had listened to other people's opinion I got what they were saying but I still stuck with mine." However, in a different school and class, Simone and David had an argument about their difference of opinion that was not easily resolved through compromise. As Vicki, a student who observed the argument, described the situation in her interview, "...she [Simone] got kind of...didn't really realise why he was thinking that!" To Vicki it seemed

that Simone was keen on convincing David that his opinion wasn't acceptable. Asked later, Simone admitted that, "...I kinda understand why he did it but I don't really agree with it!" Apparently Simone was still annoyed about David's behaviour and she added, "...he did it like to cause a stir! He was just being provocative!" It was interesting that Simone described the incident as "... kind of a friendly argument. We were like discussing it, and I was just getting a little bit angry!", whilst Vicki seemed to have interpreted the situation as a 'real' argument. Simone, on the other hand, didn't seem to mind, "... sure it was resolved but I was okay with it!". In any case, watching their argument and listening to what David and Simone had to say apparently caused other students, such as Vicki, to reflect on what was being said and on the reasons for doing so. In yet another group conflict was resolved because, "...we were both really accepting it [the difference in opinion]. We have different backgrounds." Thus knowing each other well seems to have helped with conflict resolution. One student, Dan, stated that it was okay for him to have his own opinion unless somebody else's life depended on it. Asked to clarify by the interviewer, he said that, "...then I would like other people's opinions so I'm not just the one that gets blamed for making the wrong decision." Some students seemed to realise that whilst others have the right to different opinions they personally could not agree with those views. They stated that they had come to understand that both compromises and maintaining one's own opinions are necessary as this excerpt from the interview with Emma illustrates: "... a few things made me ...well, the others and what they said...a few things were a bit worrying!" Julia asked for further clarification, "What worried you?". Emma explained, "...about other people's priorities and what they would do... like the whole human life or embryo life or something like that...", and she added, "... [in my group] we worked out some of it but I didn't really agree with what they were saying, and they didn't really agree with what I was saying but between them they agreed!". Julia asked, "...how did it feel with your friends having different opinions from you?". Emma admitted that she felt, "... alone!", yet with a smile she added, "...it was good having my own opinion rather than somebody else's!"

Summarising we can say that some students reported difficulties in the decision-making process due to conflict that remained unresolved whilst others seemed to accept conflict as okay if one was convinced of one's own standpoint. Conflict resolution and compromise seemed to be helped by knowing each other. Yet some students admitted that knowing about other people's different opinions did not necessarily cause them to change their own. Some apparently preferred the back-up by other people in the case of life-deciding decisions. The ethnographic results were confirmed by the quantitative results where just over three-quarters (77%) of the students indicated they had worked well together in trying to resolve the ethical dilemmas embedded in the stories, explaining carefully their ideas to each other and striving to reach agreement. A fifth of the group was unsure, and a small number disagreed or strongly disagreed.

Empathic Communication

Here, the focus is on developing emotional intelligence, empathy, the ability to accept and consider other people and their ideas. Most students reported that they felt their voices were listened to and their opinions accepted as legitimate. Students seemed to appreciate the opportunity to hear about other people's thoughts and opinions, and indicated the importance of knowing what others think and feel in order to care.

Sam summarised well what most interviewees had stated, "...it was kinda fun to hear what other people thought... like from their backgrounds...a lot of people haven't been as experienced as I have. " His statement also seemed to imply that he assumed that others lacked his level of life experience and that maybe in everyday life he doesn't have the opportunity (or interest?) to find out about other people's ideas. Evelyn seemed not only more aware of the differences within her peer-group but also of the importance of knowing about others' thoughts when she stated that, "...everyone has different morals and values though and because not everyone is the same ... you got to know that." Lee a student who reportedly had little to no interest in science explained that he appreciated the different style of the dilemma story science lesson, "...we were able to converse and look at each others' ideas and we learned a little bit about each other even though we have known each other for years." His views were confirmed by Dan another student who

had claimed that he didn't like science much, "...we got to see different people's ideas and what they think about it." It seemed interesting to us that these two students whose initial interest in science was reportedly low had experienced the social aspect of the dilemma learning as a positive learning experience. One of the high achievers, Megan, thought, "...it was good hearing what other people thought and basically putting my opinions towards them and trying to get them to go my way instead of their way." Her statement was interesting inasmuch as she pointed out that she had to formulate and state her opinion to others in a convincing way which suggests the necessity of deep engagement with the subject matter: one must have understood something in order to try and convince somebody else of its usefulness or validity. Yet arriving at a common understanding apparently was not always easy as Simone explained, "...I know there were a couple of other people that had a bit of a problem trying to choose who they were going to pick [to save in the dilemma story]." She elaborated that she had listened to others' opinions but she also had made sure that, "...[my voice] was heard by the whole class!" With a smile she added, "...my voice was heard!...I got really loud and yelled...the person I got angry at...did hear!" She was referring to the heated discussion she had had with David who had insisted that in the case of the dilemma story (*The Reproduction Dilemma*) it was okay to not save a particular person. At the time of the interview, Simone was apparently still coming to terms with David's argumentation. She reported that she had been thinking about this for quite some time, "...just saving one life would mean only one instead of maybe possibly two or three...That's the only way I can think about it otherwise I don't get it." This seems to indicate that she continued trying to understand Dan's opinion that seemed to stand in stark contrast to her own and that she was still trying to find an explanation for herself.

Summarising, we can say that students reported that they felt their voices were heard and their opinions accepted. All interviewees seemed to appreciate the opportunity to hear about other people's thoughts and opinions and indicated the importance of knowing what others think and feel in order to care. These results confirm the quantitative results where over three-quarters (85%) of students indicated that they had communicated empathically with other students during the dilemma story activities, being open to and respectful of other students' opinions, and relating to other students' feelings. A small number of students were unsure, with only two disagreeing.

Critical Self-Reflection and Critical Thinking

When forced to make a decision students seem to engage in both critical self reflection and critical thinking (Settelmaier, 2009). Critical self reflection occurs when a student reflects on his/her own values in order to solve a problem. Critical thinking, on the other hand, is well documented in the literature as an analytic, systematic problem-solving approach that builds largely on existing knowledge. We asked students how they went about 'decision-making' in a dilemma situation, what processes they engaged in, what values/guidelines (if any) they were drawing on when coming to a conclusion. Some interviewees reported that they did not question their own views or become clearer about what was important to them, whilst others, like Sam, stated that, "...even though we aren't as pressured as being in the real situation, we kind of simulate in our minds from past experiences when we have been under pressure, we've had to make a really tough decision, we can put that together and think about that situation as though we were in that actual position and how we'd assess it." He described well the 'constructivist values-learning process' whereby students draw on previous experiences to find a solution first before constructing new knowledge by adapting and merging old and new knowledge in order to respond to a new situation. Sam's statement was confirmed by Steve who explained that for him the dilemma learning experience had, "...made me think about my own priorities about certain situations and things like that." And Jack argued along a similar train of thought when he said, "...it made me think about the way I [would] go about it all. During the interviews Julia, the research assistant, uncovered an interesting and somewhat unexpected aspect of 'values education' in Australian secondary schools: some students had stated that they did not change or reconsider their values through the dilemma story learning experience, however, further questioning revealed that some of these students were struggling with the concept of 'value', that is, they had no clear

concept of the meaning of 'value'. This does not mean they did not have any values, only that they did not know what could be regarded as a value and thus they seemed unaware of the values they were basing their decisions on. A brief excerpt from an interview with Dan illustrates the issue well.

Julia, "Did it make you look at your values a bit more and make you think about it? Dan, "No...well, what do you mean by values?". Julia continued to explain the basic meaning of the term value, when Dan replied, "Well, when you put it that way, yes I did!"

Individual decision-making that involved critical self-reflection was experienced as difficult, challenging and sometimes confronting, as Nicky explained, "...decision making was difficult because we had to state reasons why...". Students had been asked during each of the dilemma question breaks to reflect individually at first before discussing their own ideas with others which apparently pushed some students out of their comfort zone, and some apparently did not like that very much, particularly Evelyn, "...I didn't really like the fact that I had to choose between who I'm going to save first...like messing with people's lives and sort of playing God, so I really didn't like it. I'd like it if I didn't have to make decisions!" Most interviewees, however, agreed that the dilemma-based values learning approach was preparing them for future decision-making, as Lee outlined, "...making decisions...[is] a very useful skill later on." And Emma added that whilst it was, "... frustrating when we had to choose...kind of confronting... I thought it was pretty good and [I] learned that decision making is not always going to be easy. I thought it was good!"

In relation to critical thinking, students reported that they were able to apply their existing knowledge when assessing the dilemma situation. The dilemma approach seemed to help Peta recognise the connection between real-life and science learning, "...it really did help us apply what we have learned in science." Students use their knowledge to critically assess a variety of possible solutions with a view to finding the most viable one.

Summarising, we can say that decision-making was experienced by many students as difficult, challenging and sometimes confronting – pushing some students out of their comfort zone. Some students reported that they did not question their own views and/or become clearer about what was important to them. However, further questioning revealed that some students seemed to be struggling with the basic understanding of the concept of value. Most students seemed to agree that the dilemma-based values learning approach was preparing them for future decision-making. These results were confirmed by the quantitative analysis where three-quarters (75%) of students indicated that the dilemma story learning experience had engaged them in reflecting critically on their own ideas, questioning their own views and becoming clearer about them. A small minority of students was unsure, while only 3 disagreed.

The Relationship between Science, Dilemma Pedagogy and 'Real Life'

We asked students about how they experienced the connection of the dilemma learning experience with science and 'real life'. In other words, could students see a connection between this approach, science and their lives outside of the science classroom?

Generally, students seemed able to identify direct connections between the dilemma-based values learning approach and science. They appeared to appreciate the different approach and the opportunity to see how science can be applied in daily life. As Leah reported, "...science helps me... shape my values." And she added that, "... it is good to learn about how stuff works, and [that] there is more to it than just looking at it." Evelyn confirmed Leah's views by saying that, "... yes, [the dilemma learning experience connected well with science] 'cause science is very much...like... it can be problem solving as well as the very basic elements and that sort of thing!" Sam seemed to support Evelyn's and Leah's views by saying, "...I think it had a good connection with science. We thought about it and looked in more depth...we could use our morals and compare it with science." Emma stressed that, "...without science we kinda don't know as much about the world.....how things work, how things communicate with each other and how they work together and what goes with what and what doesn't go with what... then we really get an understanding of ourselves and the way we perceive the world in kind of a more open way." Emma's view seemed to be supported by Lee who seemed to think that, "... science really helps us be open about things. Basically, it had a good connection with

science.” For Peta the dilemma approach seemed to help clarify the connection between real-life and science learning, “...it really did help us apply what we have learned in science.” Yet as Chloe explained, “... it kinda didn't feel like science! ... well, it helped me apply it to the real life situation....because the stuff that we learn for school we want it to be relevant to what we want to do or to real life instead of just being work that we're never going to use again!” Chloe's statement about the importance of relevance of students' science learning to real life summarises well the statements of most interviewees. Interestingly she stated that it didn't feel like science maybe indicating that maybe her usual science learning experience lacks this aspect of real life connection or maybe indicating a discrepancy between the way, science is usually being taught to her. Summarising, we can say that the students seemed to see a clear connection between the dilemma learning experience and science learning through connecting science content to the 'real world'. These results are confirmed by the quantitative analysis where just over three-quarters (77%) of the students indicated that dilemma story learning had helped them become critically aware about the misuse of science, and to learn that misuse or ignorance can have harmful long-term effects on their lives. A small proportion was unsure, while a small number disagreed.

Students' and Teachers' Views - Some Emergent Discrepancies

Almost all students – this includes Year 12 students - seemed to regard SRS as useful and expressed the wish that SRS should be done more often due to its direct relationship to real life. Jeremy, one of the male teachers, however, seemed more concerned about the 'crowdedness of the curriculum' and said it was “...easier to fit ethical dilemma stories into lower school classes rather than upper school classes”. He seemed to consider this to be particularly the case for classes in which university aspirations were low. In other words, SRS could be taught to the less capable students whilst he seemed to think that it would not be as useful for the more academic students. Interestingly it was one of his high ability students who spoke out most strongly in favour of the SRS approach – she and another high achiever from Ron's class both seemed to be clear that this type of learning connected science to the 'real world' and confronted them with 'real life' problems where they could apply their scientific knowledge. It appears that Ron and Jeremy viewed SRS primarily as a 'motivation tool' whilst the female teachers stressed they would not be teaching the full curriculum if values were not also taught in the classroom. Delia and June seemed to view ethical dilemma stories as a useful pedagogical strategy to overcome the apparent science-values dichotomy. It was interesting to note that the interviewed students of the male teachers emphasised how much they appreciated the different style of the dilemma lessons, and that their teachers were trying something new even though they appeared uncomfortable. Comparing the opinions of the male teachers and the female teachers in the study, it was interesting to note that the female teachers seemed to assume an inherent connection between science and values thus making it indispensable to teach values as part of science, whilst their two male counterparts seemed much more concerned to cover as much of the prescribed content as possible. It is also interesting that the female teachers' views seem to support and be supported by the majority of the students' views.

CONCLUSIONS

The results of our study indicate that a large majority of students across the sample engaged positively in a socially responsible science classroom learning environment that afforded development of critical scientific literacy skills. In particular, they (a) experienced the dilemma stories as engaging and authentic and as connecting science learning with 'real life' problems, thus making their scientific knowledge applicable; (b) had positive perceptions of their participation in dilemma learning activities which, for some of their teachers, meant an entirely new teaching style whilst, for others, it seemed to have been more of an extension of their usual teaching style; (c) perceived that their teachers had allowed them to express their opinions and 'talk to each other during class'; (d) had engaged empathically with other students in collaborative decision-making, even though sometimes this was not easy due to lack of conflict resolution skills; and (e) had reflected critically on their own ideas and values and found that the learning experience had helped

them to become critically aware of the use/applicability of scientific knowledge. Only a small minority of students consistently disagreed that they had experienced any of these aspects of the classroom learning environment. Second, the dilemma teaching approach was implemented inconsistently by teachers. The 2 female teachers closely enacted the role of dilemma learning facilitators whereas the 2 male teachers reverted to more traditional didactic teaching methods. It is interesting that, although the largely positive attitudes of most students and of the female science teachers stand in contrast to the less than favourable attitudes of the two male science teachers, the latter expressed surprise at how well dilemma teaching had worked in their classrooms, especially the positive engagement of their students. These results are consistent with our earlier research (Settelmaier, 2009) and add further evidence to the claim that a socially responsible science education based on ethical dilemma story pedagogy offers a promising means to develop critical scientific literacy skills with which students can engage as socially responsible citizens in informed decision-making about the appropriate use of science for addressing global issues such as climate change and environmental sustainability. The results suggest that if this type of values learning is to be more widely integrated into science classrooms of the future then transformative professional development is needed that engages teachers in reflecting critically on their (hidden) assumptions about what constitutes legitimate science education and what does not; in particular, on the science-values dichotomy. Because many pre-service science teachers are likely to regard values learning as 'not really' science education, 'value-added' reform of science teacher education programs is needed. Such an approach would emphasise the importance of integrating values learning into the science curriculum, not as a luxury that may be afforded if there is sufficient time available but rather as a vital necessity if the decision-makers of the future are to learn necessary skills for preventing the world from repeating the environmental disasters of the past. Science teachers have a pivotal role in this essential educational process. Another promising approach to integration that we are investigating with our current research is via inter-disciplinary teaching in which science teachers collaborate with teachers of other subjects (e.g., languages, mathematics, society & environment) to develop and teach ethical dilemma stories, including students in learning to write their own stories.

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REFERENCES

- Department of Education, Science and Technology (2005). *National framework for values education in Australian schools*. Canberra, ACT: Commonwealth of Australia.
- Fraser, B. J. & Fisher, D. (1983). Use of actual and preferred classroom environment scales in person-environment fit research. *Journal of Educational Psychology*, 75, 303-313.
- Guba, E. G., & Lincoln, Y. S. (2005). Paradigmatic controversies, contradictions, and emerging confluences. In N. K. Denzin & Y. S. Lincoln (Eds.), *The Sage handbook of qualitative research* (3rd ed., pp. 191-215). Thousand Oaks, CA: Sage.
- Hodson, D. (2008). *Towards scientific literacy: A teachers' guide to the history, philosophy and sociology of science*. Rotterdam, The Netherlands: Sense Publishers.
- Settelmaier, E. (2003). *Transforming the culture of teaching and learning in science: the promise of moral dilemma stories*. Unpublished PhD, Curtin University of Technology, Perth, AUS.
- Settelmaier, E. (2009). *Adding zest to science education: Transforming the culture of science classrooms through ethical dilemma pedagogy*. Saarbrücken: VDM.
- Taylor, P. C., Fraser, B. J. & Fisher, D. (1997). Monitoring constructivist classroom learning environments. *International Journal of Educational Research*, 27(4), 293-302.
- Taylor, P. C., Settelmaier, E., & Luitel, B. (in press). Multi-paradigmatic transformative research as/for teacher education: An integral perspective. In B. J. Fraser, K. G. Tobin

- & C. McRobbie (Eds.), *International handbook of science education*. The Netherlands: Springer.
- Tytler, R. (2007). *Re-imagining science education: Engaging students in science for Australia's future*. Camberwell, Vic: ACER Press.
- Vitz, P. C. (1990). The use of stories in moral development: New psychological reasons for an old education method. *American Psychologist*, 45(6), 709-720.