Beliefs, values, ethics and moral reasoning in socio-scientific education

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The realisation to integrate science, ethics and morality is recognised with growing impetus in recent years (as noted with introducing the Australian Curriculum *Science as a Human Endeavour* strand), to develop sophisticated epistemologies of science, which includes an appreciation of the social context including ethical thinking. To fulfil the aim where pedagogy and curriculum enable students to integrate ideas about scientific issues and their own values, beliefs and ethics, educators need to understand how an individual naturally construes these issues. This paper is based on an investigation to address the need, in particular, how students construe genetic engineering issues as ethical issues and/or moral problems and how these values (faith/beliefs) influence their decision making regarding these issues, in a ten-week Year 10 biotechnology program in a faith-based school. Using an interpretative case study approach, a mixed method data collection and action research, analyses of instructional strategies, students' beliefs/values/attitudes and achievement outcomes were evaluated. The investigation is unique as it presents one of the few studies that incorporate faith values in the ethical frameworks, to explore the connection between cognitive learning, moral reasoning and moral development, and in the wider sense, between scientific literacy and ethical reasoning. It suggests that allegiance to belief systems and ideologies can sometimes override the influence of one's own sense of fairness in making decisions of moral rightness, and this has implications in mapping out curriculum for moral education and socio-scientific education.

Introduction

Over the last decade, there has been a confluence of factors and trends in curriculum development, educational theory and practices, and changing national policies in the Australian educational scene. Values education has emerged to be a prime focus in writing a school curriculum on some common ground (Acar et al., 2010; Fensham, 2002; Jorgensen & Ryan, 2004; Sadler & Zeidler, 2005b; Zeidler, Herman, Ruzek, Linder & Lin, 2013). A student-centred approach to teaching practices has also gained wider acceptance. Socio-scientific issues as a vital area of concern in improving active responsible citizenship (Aikenhead, 2006; Driver, Newton & Osborne, 2000; Fensham, 2009; France, Mora & Bay, 2012; Kolsto, 2001; Tytler, 2007) is increasingly integrated in a number of cross-disciplinary subjects. In recognising this growing trend towards socio-scientific relevance and responsible citizenry with scientific literacy, the Australian Curriculum, Assessment and Reporting Authority (2014) identified 'developing ethical reasoning' and 'decision making' as key attributes in educational outcomes. Such a movement necessitates how science educators can constructively and creatively address these rapid changes.

The nature of socio-scientific issues is usually controversial and characterised by dilemmas and debatable from various perspectives. As such, they are usually inextricably linked with morality and ethics. Bioethical issues raised in the field of biotechnology include genetic

engineering and reproductive technology, and these aspects of biotechnology are pertinent in highlighting the significance of moral and ethical considerations in decision-making regarding science-related issues (Sadler & Zeidler, 2004). Extensive research by bioethicists and science educators in connecting the socio-scientific issues of genetic engineering, such as cloning and gene therapy, to moral reasoning have been conducted (Evans, 2002; Haker & Beyleveld, 2000; Lee, Yoo, Choi, Kim, Krajcik, Herman & Zeidler, 2013). Such research underlined the importance of socio-scientific decision-making that involves the consideration of morality and ethics.

In making the connection of socio-scientific issues with morality and ethics, this implies that socio-scientific issues are *moral* issues. By 'moral', domain theorists suggest that such a quality is an intrinsic aspect of particular events, situations or issues irrespective of the culture from which the incident arises (Nucci, 2001). They suggest that social knowledge and decision making reside in one of three universal domains: conventional, personal and moral. The conventional domain categorises issues that are best handled with the application of social norms. The personal domain represents decisions that are subject to an individual's personal choice and preference. On the other hand, the moral domain is defined by universally recognised prescriptions based on conceptions of human welfare, justice and rights. The domain account of social knowledge would suggest that socio-scientific issues are inherently moral because they involve objective, prescriptive and generalisable standards.

At least three broad moral philosophies could theoretically be applicable to socio-scientific decision-making: deontology, consequentialism and care-based morality. These three aspects are taken into consideration in four of the ethical frameworks (rights and duties [deontological], maximum benefits [utilitarian/consequentialism], virtue-based and making decisions for oneself) used in the present study. The inclusion of the religious values (as an alternative framework) provides *another* avenue for the exploration of the moral aspects of socio-scientific decision-making. The present study highlights the importance of the individual in playing a critical role in assessing the extent to which morality (including religious values) contributes to decision making. The process by which individuals assess the morality of a situation has been termed as *construal* (Bersoff, 1999).

According to Hoffman (2000), for a person to determine the use of deontological principles, evaluate moral consequences or respond to a situation with a care perspective, s/he must first recognise that the situation involves moral considerations. *Construal* is the process by which individuals recognise, perceive, and/or interpret particular situations or decisions as moral (Saltzstein, 1994). Construal does not necessarily have to be a conscious process. In fact, it is more likely a person's immediate reactions, which are informed by emotions, previous experiences, and habits, that contribute significantly to construal (Bersoff, 1999). Although bioethicists (Evans, 2002; Haker & Beyleveld, 2000) and science educators (Andrew & Robottom, 2001; Lee et al., 2013; Zeidler et al., 2002) may profess the intrinsic morality of socio-scientific issues, the ultimate arbiters of morality are the individual decision-makers. In order for moral considerations to contribute to socio-scientific decision-making, the individual decision-makers must construe *socio-scientific issues as moral problems.*

The realisation to integrate science and morality is recognised with a growing impetus to develop sophisticated epistemologies of science, which includes an appreciation of the social context (including morality) in which science operates, among students (Abd-El-Khalick & Lederman, 2000; Kolsto & Ratcliffe, 2008; Passmore & Svoboda, 2013; Saunders & Rennie, 2013; Siebert & McIntosh, 2001). In order to move to a place where pedagogy and curriculum enable students to integrate ideas about scientific issues and their own values and ethics, the community needs to understand how an individual naturally construes these issues. The present study is an attempt to address the needs, in particular, how students construe genetic engineering issues as moral problems and how their moral values (faith and/or religious) influence their decision-making regarding these issues. This study was also undertaken to design, implement and evaluate a decision-making ethical framework in which students consider their *values* about a socio-scientific issue and assess different alternatives.

The investigation focussed on the use of a student-centred model in a Year 10 biotechnology class taught over a period of 10 weeks in a Christian college in Perth, Western Australia. In this study, the focus was on the use of ethical frameworks incorporating Christian values to enable students confronted with controversial dilemmas in socio-scientific issues. The study evaluated the effectiveness of using the ethical frameworks as a pedagogical strategy to facilitate students' critical thinking, informal reasoning, argumentation and decision-making skills. In working towards the objective of the research, the following two research questions were posed.

1. How effective is the simple framework in developing students' ability to reason analytically and make decisions about ethical issues?
2. In what way does the use of the five ethical frameworks affect students' ability to reason analytically and make decisions about ethical issues?

Method

A mixed method design was used to address the issue of effectiveness of ethical frameworks in enabling students to develop ethical reasoning skills in a Year 10 biotechnology program. This ten-week program focused on gene technology, genetically modified food, genetic engineering and reproductive technologies. Each student attended six periods of lesson/practical per week, lasting 50 minutes each. Lessons were in the form of lectures (with *PowerPoint* presentation) or a laboratory session that covered two periods, usually once a week. Students completed weekly readings and homework (review exercises). Students also completed activities involving case studies and media articles as well as a formative and a summative assessment.

The quasi-experimental design involved a comparison group of 32 students taught by a biological science teacher, and an experimental group of 31 students taught by the researcher. These two classes typified a sample of Year 10 class in a suburban school in Australia. All students were 14 to 15 years of age with quite similar socio-economic and religious backgrounds. Data were collected from a pre-program questionnaire and a post-program questionnaire. A triangulated mixed methods design was used in which different

but complementary data was collected during a ten-week program. The comparison group used the simple ethical framework while the experimental group used the five ethical frameworks. The practices of these frameworks were conducted over a similar period of time for both groups. Both comparison and experimental group teacher worked together to ensure that all teaching resources and strategies (apart from the use of the ethical frameworks) were similar and utilised to the same extent.

Quantitative data from the pre- and post-program questionnaires were used to determine the effectiveness in the use of the ethical frameworks. The questionnaires assessed the students' *understanding* and *ethical thinking*, *attitude* and *opinions* of biotechnology, scientific knowledge and ended with a section on the students' *religious faith*.

Concurrently, qualitative data such as students' written responses to case studies, interview transcripts, observation of participants by the researcher, journals and audio-recordings of small group discussions, were used to explore the ethical reasoning (through informal reasoning approaches) and argumentation skills development. For the purpose of this research, the focused interview is used (Merton, Fiske & Kendall, 1990). In this case, a student or a group of students was interviewed for a short period of time, about 10 to 15 minutes. Both comparison and experimental groups were given the same set of 10 questions. Each interview was recorded using an audio-digital recorder and transcribed. Altogether, there were 16 interviews (8 rounds for the comparison group and 8 rounds for the experimental group). The data collected from the interviews were triangulated with classroom observations, student questionnaires and class case analyses to identify emergent patterns or themes characterising development of ethical thinking and different forms of reasoning skills.

Classroom observations for the present study were made with reference to the type of teaching strategy for socio-scientific issues that engaged the students; for example, small group discussions, the type and level of reasoning employed by the students for each context and any development with the use of the simple framework or the five ethical frameworks in facilitating the individual student's and small group's argumentation, reasoning and decision-making, as well as students' attitude and overall response, positive or negative towards science learning using socio-scientific issues.

The reason for collecting both quantitative and qualitative data was to bring together the strengths of both forms of research to compare, validate and corroborate results.

Both qualitative and quantitative methods were designed to ensure both internal and external validity were addressed. The internal validity criteria was met by representative sampling, prolonged engagement and persistent observations in the field, triangulation of methods, triangulation of sources, members checking, peer examination and measures to minimise researcher's bias. To ensure external validity and reliability, a detailed and thorough description of data was collected and analysed, and the position of the researcher and the participants were given much consideration when using multiple methods of data collection and analysis and providing a detailed and comprehensive audit trail.

The choice of ethical frameworks and the rationale

In most of the current models of teaching socio-scientific issues, teachers present resource materials (real life situations, scenarios, moral dilemmas, etc.) with a range of different viewpoints and invite students to articulate their opinions based on their evaluation of the evidence (Dawson, 2003). In this regard, the choice for the comparison group was to utilise a simple framework that would enable students to explore a range of viewpoints serving as an example of a template that may be most likely and currently used in existing teaching approaches to socio-scientific issues. This simple framework takes into consideration the positive and negative consequences of choices made; that is, by weighing the pros and cons of a number of viewpoints, students seek to establish some kind of justification based on the range of viewpoints.

The simple framework used by the comparison group is set in contrast with that of five ethical frameworks utilised by the experimental group. Four of the five ethical frameworks were based on the work of Reiss (2008) which provided a selection of ethical perspectives drawn from well-established approaches to ethics and ethics education. These four established approaches are rights and responsibilities, consequentialism (specifically in the form of utilitarianism concerned with both the beneficial and harmful consequences of action); autonomy (recognition of the individual's right to free choice) and virtues (emphasising motives and good characters rather than actions). In addition to these four, the *fifth* one added by the researcher incorporates a Christian perspective, not only as a means of studying a particular religious moral outlook (if expressed, and how, in a predominantly religious institution) but also to explore the possible link between faith and ethical/moral reasoning development.

Table 1 provides a list of the five ethical frameworks that was used by the experimental group.

Evaluating informal reasoning and decision making

Development of test instruments for measuring students' competence in reasoning and decision making are still subject to debate, because science education research on these competence areas is still at a relatively early stage of development, and measurement procedures are more intricate in comparison with test instruments for scientific knowledge, for example. With regard to the assessment of socio-scientific competence in reasoning and decision making, researchers have explored the use of trade-offs (Seethaler & Linn, 2004; Wilson & Sloane, 2000), and cut-offs in weighing decision criteria (Hong & Chang, 2004), and prioritising conflicting values (Bogeholz & Barkmann, 2005; Jimenez-Aleixandre, 2002; Kolsto, 2006) or reflecting on argumentation and reasoning processes (Sadler & Zeidler, 2005ab). These are commendable efforts to identify students' competencies as well as development of these competencies. Eggert and Bogelholz (2010) developed a test instrument to measure competencies in socio-scientific decision making based on the *Rasch Partial Credit Model* and succeeded in establishing a hierarchy of different strategies in terms of increasing difficulty. Reiss (2008) developed a coding

system based on the number of ethical frameworks used by students in writing their examination reports after completing the Salters Nuffield Biology course for 16-18 year-olds.

Table 1: Five ethical frameworks: A summary

Sources: EF1 to EF4 from Reiss (2008, pp.900-901);
EF5, the Fifth Ethical Framework, from Yap (2013, pp.33-34)

EF1 Rights and duties (deontological)	Rights define what people can expect as their due, so far as it is under the control of people or human society. There is always a duty associated with a right, though in many cases, the duty on other people is simply that they do not interfere with or prevent others claiming their rights. Any right or individual has relies on other people carrying out their duties or other people's rights may be neglected.
EF2 Maximising the amount of good in the world (utilitarian)	This framework balances the benefits of an action against the risks and costs. It promotes the common good to help everyone have a fair share of the benefits in society, a community or a family. This framework is often described as 'the greatest happiness for the greatest number'. It could be seen as a 'right' to override the rights of the individuals in order to bring about happiness in the wider community.
EF3 Making decisions for yourself	Autonomy is concerned with the respect due to individuals. People act autonomously if they are able to make their own informed decisions and then put them into effect. The principle of autonomy is the reason why people should be provided with access to relevant information, for example, before consenting to a medical procedure or taking part in a clinical trial.
EF4 Leading a virtuous life	Justice is about equality, fair treatment and the fair distribution of resources of opportunities. For example, private medical care could be seen as making superior resources available to those who can pay; alternatively, it could be seen as providing a 'choice'. This framework supports the moral 'rightness' or 'wrongness' of actions. An action can be described as right or wrong independently from any consequences of the action. It is not the consequences that make an action right or wrong but the principle or motivation on which the action is based. Traditionally, the seven virtues were said to be justice, prudence (i.e. wisdom), temperance (i.e. acting in moderation), fortitude (i.e. courage), faith, hope and charity.
EF5 Christian (moral) ethics	This framework is based on principles and standard stipulated in the Scripture (Holy Bible). The Scripture provides the basis and motivation for which a decision is based. This framework promotes the values undergirding the belief which centres on the person, the work and the teachings of Jesus Christ, whom, through his life, death and resurrection points to the existence of a Triune God and to the nature and character of God, the Father, and whose work continues on earth is instrumental by the empowered community of faith – the Christians.

To respond to some of the difficulties encountered in students' decision making competence, Kolsto (2006), among others, suggested that presenting different reasoning patterns can be a means to induce meta-reflection about decision making processes and inherent value conflicts and thus can be a way of fostering students' decision making competence. The present study seeks to complement the evaluation of decision making competence by also identifying and evaluating the number of reasoning patterns used in resolving dilemmas of socio-scientific issues, as well as using a decision-making code as a measuring instrument.

Use of a decision-making code

For assessing students' decision-making skills, the researcher developed a code (Table 2) incorporating the essential components of sound decision making skills. Sound decision making skills demonstrate a reasonable understanding why a decision has to be made, and an understanding of the source of the problem (Ratcliffe & Grace, 2003). This was accompanied by a consideration of a plausible number of options (Eggert & Bolgeholz, 2010). The options could refer to, for example, the number and type of ethical frameworks used, which was indicative of an integrated approach in shaping the argumentation process towards decision making. Attention was also given to the consequences of weighing the benefits and risks of a technology or practice employed (Siegel, 2006). The ability to monitor and guide one's own thinking process, or metacognition (Kolsto, 2006), was determined by the kind of question posed or type and sequence of reasoning used to build towards a well-informed decision.

Table 2 is a non-hierarchical array of features that constitute sound decision making in dealing with socio-scientific issues in the classroom activities. This list of codes was developed by the researcher as a means of identifying the progress (if any) of the comparison group and the experimental group in their use of the simple framework or five ethical frameworks respectively.

Table 2: List of codes on the features of sound decision-making

Code	Features of sound decision-making
A	Understanding why a decision is to be made
B	Integrating of two or more ethical frameworks
C	Identifying benefits and risks in the consequences
D	Establishing sound evidence (scientific knowledge, intuition, values)
E	Thinking through the thinking process (metacognition)
F	Attitude (openness, engagement, motivation, etc.)

Identifying the patterns of informal reasoning

To identify the patterns of informal reasoning and the role of morality in the decision making process, the researcher adapted the model used by Sadler and Zeidler (2005a). Sadler and Zeidler's research was based on evidence demonstrated in the form of rationalist, emotive and intuitive informal reasoning.

1. Rationalistic informal reasoning described reason-based considerations.
2. Emotive informal reasoning described care-based considerations.
3. Intuitive reasoning described considerations based on immediate reactions to the context of a scenario.
4. Moral informal reasoning described considerations based on one's values and belief systems.

The researcher has added moral informal reasoning to Sadler and Zeidler's (2005a) three forms of informal reasoning. This is because students in both comparison and experimental groups have been observed to state their values and beliefs in the pre-questionnaire, even though they were not explicitly taught or made known at the beginning of the term. Also, students may rely on a combination of these reasoning patterns as they worked to resolve individual socio-scientific scenarios. The researcher has coded the combinations of reasoning approaches as shown in Table 3.

Table 3: Code for different combinations of reasoning approaches

Code	Reasoning represents
R	Rationalistic only
E	Emotive only
I	Intuitive only
RM (M)	Rationalistic and moral
EM (M)	Emotive and moral
IM (M)	Intuitive and moral
No response	Null response

The framework of informal reasoning can be visually conceptualised in the form of a Venn diagram as shown in Figure 1. Each circle represents one of the approaches of informal reasoning (i.e. rationalistic, emotive and intuitive) with moral reasoning represented by a shaded equilateral triangle enclosing a non-shaded circle, denoting a complementary set of moral reasoning (Yap, 2013).

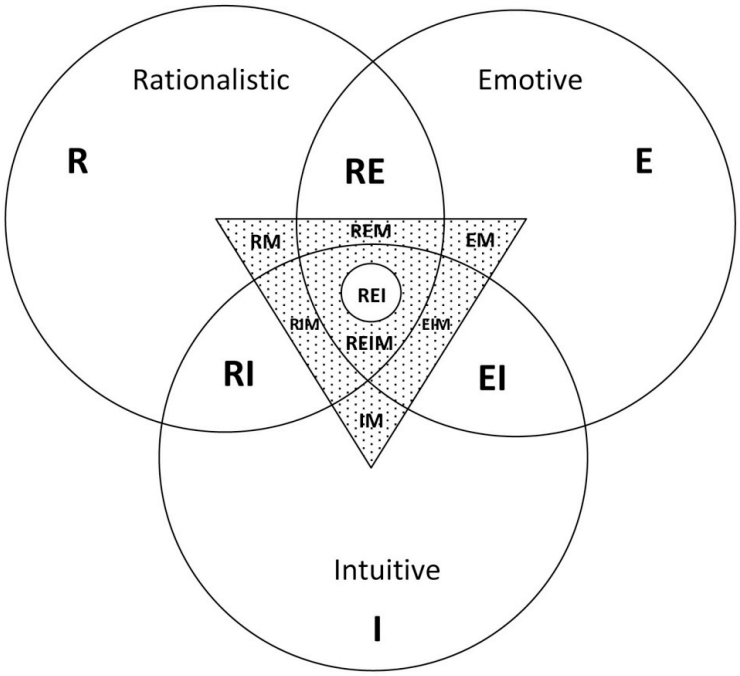

Figure 1: Display of the emergent patterns of integrated informal reasoning

Samples of students' responses

Table 4 is a summary of student responses and their use of informal reasoning approaches from the experimental group.

Table 4: Student responses and uses of informal reasoning approaches

Rational	Students used rationalistic thought processes to guide their decision making in at least three out of four scenarios presented to them. They made rationalistic calculations based on a variety of factors, such as patient rights, parental responsibilities, the availability of other treatment options, side effects and future applications. *3 examples: [R]* On Genetically Modified Food - Agree – "It helps fight world hunger and malnutrition." Student S39 On Genetically Modified Food - Disagree – "It would create an even larger gap between the rich and the poor. We do not know all of the dangers of genetic modification." Student S46 On Therapeutic cloning - Agree - "Many people are dying, waiting for organs and from the rejection of new organs. Therapeutic cloning would solve the problem." StudentS53

Emotive	Students developed this reasoning from a care perspective in which empathy and concern for the well-being of others guided decisions or courses of action. Students frequently articulated ideas and positions that reflected concern for individuals that would potentially be impacted by their decisions. Considerations were made from a relational perspective. *3 examples: [E]* On Genetic Screening - Agree to some extent – "I agree with using it to get rid of genetic disease but I don't agree with using it to make designer babies. It is one of my worst fears to have a baby who inherit my condition." Student S24 On IVF and Genetic Screening – Disagree – "This way of making a child is very unnatural and not at all how God planned it. It is like you are taking over God's role which is wrong." Student S25 On Cloning of humans – Disagree – "If I couldn't have a baby with my wife, I would adopt because that's how it is and there are many children out there who need parents." Student S13
Intuitive	Students based their informal reasoning on an immediate reaction to the context of a particular scenario. This is not often a 'gut-level' reaction that could not necessarily be explained in rational terms. Intuitive feelings may not be rational but because they contribute to the resolution of socio-scientific issue, they may be considered a type of informal reasoning. *3 examples: [I]* On Genetically Modified Food – Disagree – "For thousands of years, we have survived without GM crops. I don't think GM foods could solve world hunger as this can only be treated by getting the food to places that need it in the first place." Student S17 On Therapeutic Cloning: Agree – "It is for the better of everyone." Student S20 On IVF and Genetic Screening – Disagree to some extent –"Every child is God's creation and if we are to choose features and intelligence, it is no longer the work of God. I would not pick any child's features and talents. I would like him to be entirely made by God." Student S27
Moral	Students based their informal reasoning on a set of beliefs or values or a set of morals they have due to personal convictions, religious or cultural factors. *3 examples:* *Moral and Intuitive [MI]* On IVF and Genetic Screening: 'Strongly Disagree – "It is against my own beliefs and values." (M) Student S31 *Moral and Rational [MR]* On IVF and Genetic Screening – Disagree – "I think that changing humans to fit our image instead of God's is 'playing God'(M) and can have many risks and dangers. God made us perfect the way we are –whether we have Down Syndrome, black eyes or bald. He loves us the way we are. Changing ourselves to fit human image could affect our relationship with God. It could also have long term effects." Student S23 *Moral and Emotive [ME]* About IVF and Genetic Screening – Disagree – "If someone wants to change their baby genes, would God's already have that planned and therefore plan for the baby to be like that? It is wrong to try to change God's order." Student S20

The following students' responses are selected as they demonstrate clearly the use of each of the five ethical frameworks from the experimental group; in most cases, students stated them explicitly (as headings) while others reasoned implicitly within a particular framework without mentioning it at all.

Table 5: Sample of students' responses demonstrating use of each five ethical frameworks

Balancing rights	"Everyone has the right to live and it is concerning a child, then the parents have the duty to take care of their child and ensure they have the best life possible. But every unborn child has the right to develop naturally and without the interference of new genes in the unborn child's life." Student S11 "If I were Anna's parent(s), I would obviously spend money on the sick child, but genetically engineering a child should be avoided because it denies the child's uniqueness and there could be complicated involved, as the story unfolds in the movie." Student S11 "I believe that the child that is genetically engineered has the right to decide to donate her body parts or not. The recipient child has the right to decide whether she wants to receive the organ." Student S19 "It would not be right to make another child suffer for the sake of another, especially if the child does not want to. It is unfair to force a child to suffer, if he/she refuses." Student S21[from a care perspective]
Maximising benefits	"If the designer [genetically engineered] child was able to save the life of her sister and survive, the benefits would be enormous. It is worth the effort as two lives continue living instead of one." Student S17
Making decisions for yourself	"I would have given more choice to Kate (the recipient child) as she might have been ready to die before Anna's conception (saviour sibling). Kate would have to live with a large burden of guilt by having a sister made solely to donate to her without choice. I would make a decision based on Kate's well-being as it is her life in the balance." Student S2
Virtues	"As the parents, we should not genetically engineer a child just to help another child. The sick child is not going to live as long as most healthy people anyway; rather than prolong her suffering, we should just let her go." Student S19 "I would try to find a donor to give my child what she needed. There are many people who donate. I would use the 'leading a virtuous life' ethical framework and try to do as much as I could to help the child. But I would not go as far as making a designer baby to give parts away." Student S8
Christian values	"If a child with the disease was dying, God would have a reason for it. The parents should pray and ask God for strength and wisdom. The parents should not have a 'designer child'." Student S23 "Everyone is made and designed by God for different purposes and to 'design' a person eliminates part of the God-given uniqueness. [uniqueness of each individual bearing God's image and God's special design]" Student S23

Table 6 illustrates students' responses and lines of reasoning based on their faith values, from both comparison and experimental groups.

Table 6: Students' written responses and lines of reasoning

Against God's created order Not natural Alter God's creation	*Scenario 1 - Genetically Modified Food* "Although changing the genes may look promising, what research has been done on how it may benefit or harm human health. God made the plant that way and we are doing nothing but messing with his creation by modifying the genes." Student S11
Playing God	*Scenario 2 - IVF and Genetic Screening* "God made you as you are and with a purpose. Stick to it. Playing God is wrong use of technology." Student S36
Displacing God	"This way of making a child is very unnatural and not at all how God planned it. It is like you are taking over God's role which is wrong." Student S25
	"I disagree with the selection of traits as it is a sort of telling God that you can improve his creations." Student S46
God's plan and God's will	"I don't think people should be able to select the gender of a child, let alone eye colour or intelligence. It is unethical, unnatural. It may be going against plans that God has for your life and your children." Student S21
Man made in God's image (Genesis 1:27)	"God has created everyone in his own image, and who are we to alter his creations? (Genesis1)" Student S27
Biblical view of life Status of embryo	"Status of embryo – An embryo is actually a baby. If you change it, you are messing with a real human being, not just a blob (a piece of human tissue). It is unnatural." Student S15
Affects relationship with God	"Affects our relationship with God. Changing ourselves to fit our ideal human image could affect our relationship with God. It could have long term effects." Student S23
Uniqueness of God's creation	*Scenario 3 - Reproductive Technologies* "Everyone is supposed to be different and creating a baby genetically identical to yourself is not natural and against God's will." Student S41 "Uniqueness of God's creation – Cloning is a false form of creation and there can only ever be one unique version of yourself that is created by God." Student S16
God's role in creation	"God is the only one who knows your body. I think that it is wrong and they should just adopt a child instead." Student S1 "Cloning is wrong. God would not be pleased because he created man and woman to have babies. And by cloning, it is a sort of saying to God that man can do a better job than him." Student S4
Praying	"This is not the way God wanted us to have children. We should instead pray for miracle and not try to be God." Student S46

Nature of God	"I don't agree with this as it is going against God's word. It is unnatural and immoral." Student S53
God's will	"God has provided natural ways to have children such as adoption." Student S55
Use of scientific knowledge and expressed change of conviction	*Scenario 1 - Genetic Modified Food* "I now see and agree why GM food can be good. Like crops that are GM could grow in regions of severe drought, such as Africa. However, just because they may greatly help in the fight against world hunger and malnutrition does not mean it is ethically right. I think the way God created plants is the best way to keep them that way. The question to ask is whether changing God's creation to aid another human being is agreeable. To this, I say, to some extent, that is agreeable. Changing plants it fine as long as it helps others. However, this could lead to ethical problems concerning other aspects of GM food." Student S28 *Scenario 2 - IVF and Genetic Screening* "I agree that genetic screening for the sole purpose of searching genetic disease is okay. However, I believe the eye colour and gender difference should not be meddled with. First, I feel that a child is a gift from God. Changing their looks would be like receiving a special present from someone and then saying you will change it because you do not like it. Second, genetic screening has the potential to diagnose genetic conditions in a baby. This would help in the emotional and physical preparations for this baby. However, as with all technology, there come some people who will misuse it. This is why I think technology should be used only to a certain degree." Student S28

Research findings

In assessing the effectiveness of the simple framework in developing the comparison group students' ability to reason analytically and make decisions about ethical issues, the simple framework has been helpful in enabling students to think about options and alternatives, and students begin to explore from a wider range of viewpoints. The current model of using pros/cons and benefits/risks demonstrated some improvement in engaging students and a slightly improved learning outcome. This was evident from the use of at least one reasoning approach to justify their choices made by an increased number of students in the post-program questionnaire and the slightly improved post-knowledge test scores.

Data analysis was based on the collation of reasoning approaches from the three scenarios: namely, genetically modified food, genetic screening and reproductive technologies. Table 7 shows the collation of the informal reasoning approaches. The types of reasoning approaches utilised by both comparison and experimental groups were somewhat similar for all, except for rationalistic reasoning which saw an increase from 19% to 37%, and a decrease from 37% to 21% in intuitive reasoning with the

experimental group. This may be indicative that the use of ethical frameworks in the experimental group had enabled students to move beyond emotive and intuitive response to develop a more logical or reflective approach; hence a greater use of the rationalistic reasoning type. It was, however, not a substantial difference to allow a conclusive statement. It would appear that moral reasoning and the use of religious values had remained at fairly similar levels. This was not surprising given that the introduction of socio-scientific issues does not change moral or religious convictions but provide a means by which a viewpoint may be better expressed.

Table 7: Collation of informal reasoning approaches

Reasoning type	Comparison pre [32]	Comparison post [32]	Experimental pre [39]	Experimental post [29]	Comparison percentage		Experimental percentage	
					Pre	Post	Pre	Post
Rational R	22	22	25	45	18%	17%	19%	37%
Intuitive I	28	44	48	26	23%	33%	37%	21%
Emotive E	7	11	7	6	6%	8%	5%	5%
Moral M	28	36	40	35	23%	27%	31%	29%
No response	39	19	10	10	31%	14%	8%	8%

Across the three scenarios, it was noted that between the pre and the post, predominantly for the experimental group, there was a shift from using one or two reasoning towards using more (two or more). This reflected a greater complexity in their reasoning patterns and an ability to integrate a number of different reasoning approaches.

Interestingly, Table 8 indicated that when comparing the use of the number of reasoning approaches among the post of comparison and experimental, more students from the experimental group were using two or more reasoning approaches compared to the comparison group.

Table 8: Comparison of the number of reasoning approaches in the post tests of comparison and experimental groups

Use of reasoning approach	Scenario 1		Scenario 2		Scenario 3	
	Comp	Exp	Comp	Exp	Comp	Exp
1	10	0	4	0	6	2
2	12	17	7	10	10	9
3	4	9	13	14	6	12
4	-	-	-	3	1	1
No response	2	2	4	1	5	4

The increase in the number of students using two or more reasoning approaches may be attitudes to the use of ethical frameworks that encouraged students to utilise multiple options/ choice framework to evaluate and to build up the argumentation process for a decision to be made. Or it may also be explained that students are learning to explore socio-scientific issue from various perspectives, and use of ethical frameworks helped

students to achieve a greater flexibility in the perspective-taking and hence influence the increased sophistication in their reasoning approach. However, the sample size is rather small and this limitation must be given due consideration and caution has to be made not to universalise this.

There was also a notable attitude change - more positive and greater awareness of the benefits of biotechnology and with the gain in knowledge, also a greater discretion on the use of biotechnology, based on the questionnaires evaluating the students' attitude towards biotechnology, interviews and students' journals.

Based on the students' written responses in the comparison group to the three scenarios, a simple framework such as pros/cons and benefits/risks were found to be useful, as it helped students to think about options and alternatives they may not normally think of themselves. Often the responses were a few words or a few sentences, but this framework may have helped to facilitate their thought processes, so that there were more students responding to the post-program questionnaire than to the pre-program questionnaire. In 59% of the cases in pre-program questionnaires and 77% in post-questionnaires, one to two reasons were stated to justify their viewpoint (Table 9).

Table 9: A sample of comparison group students' pre- and post-program written responses on 'The Three Scenarios'

Scenario	Pre-program response	Post-program response
Scenario 1 Genetically Modified Food	Agree - No Response S37	Agree - 'This could make food cheaper, taste better and have better nutritional value.' S37
Scenario 2 IVF and Genetic Screening	- Don't know what it is! S38 No Response	Disagree - 'Because I don't think it is right to pick the gender of your baby or what it should look like.' S38
Scenario 3 Reproductive Technologies	- No Response S51	Agree - 'It allows the infertile couple to have children and live normal lives.' S51

In the comparison group students' written responses justifying their viewpoints with one to two reasons, 59% of the students responded in the pre-program questionnaire compared with 77% in the post-program questionnaire across the three scenarios. It may perhaps be inferred that, given the instruction and the practice of the simple framework, more students were able to respond with confidence by providing some form of reasoning for their viewpoints.

The student responses presented in Table 10 were selected as illustrative of one to two reasons characterising the type of reasoning approaches observed in the comparison group. It may be inferred from the comparison group students' post-program responses that there was a reasonable level of increased awareness of ethical thinking and that the simple framework provided a starting point and some means of justifying their viewpoint with a reason and/or a claim to substantiate a particular stand they chose to take.

Table 10: A sample of comparison group students' pre- and post-program written responses on 'The Three Scenarios' (characterised by one to two reasons)

Scenario	Pre-program Response	Post-program Response
Scenario 1 - GM Food	Disagree - 'Even if it can be of great help to people in the sense that it could be healthier and help fight world hunger, GM food might make the earth adjusted to it and people become dependent on it. The earth might not produce any more natural things easily. We might have to use more and more to keep the same quality.' S41	Agree - 'I think that GM food is not that bad because by doing this, we could produce better quality food and more food which would help people. I do reckon though there are dangers involved such as it could upset nature and can produce result that was not intended.' S41
Scenario 2 - IVF and Genetic Screening	Disagree - 'I disagree with the selection of traits as that is some sort of telling God you can improve his creations. If it is a life-threatening disease, I think we can modify the genes.' S46	Agree - 'I agree with the technology (IVF and Genetic Screening) as long as it is used for medical reasons to help people and not for vanity. By medical reasons, I mean it could save people or increase quality of life. But for vanity purpose (such as becoming more attractive with 'blue eyes', etc), it is unethical because it puts pressure on a child to become someone he is not. This can also create a bigger gap between the rich and the poor.' S46
Scenario 3 - Reproductive Technologies	Agree - 'This would help infertile couple to have children but they could also adopt a child. I understand that sometimes a parent want to have their very own children.' S61	Agree - 'I agree but it could be a last option the couple think about adopting or surrogacy.' S61

For the experimental group, the five ethical frameworks provided a basis to align their views and served also as a basis to provide reasons for the decision making. Evidence from students' work (Table 5) demonstrated how the frameworks provided a kind of scaffold to integrate new knowledge. The provision of the five ethical frameworks for the experimental group showed that the students used it as a starting point to develop competence in argumentation and reasoning. The usefulness of such frameworks was confirmed in the research undertaken by Acar et al. (2010), who pointed out that educators should give more space and respect to student values in socio-scientific issues (refer also to Bell & Lederman, 2003; Ekborg, et al., 2013; Sadler & Zeidler, 2005a; Zeidler, et al., 2013). One way of addressing this deficiency was to provide the values framework for students just to begin to consider, or bring to fore, or make explicit the underlying beliefs or values that actually shaped their decision making. In this respect, this study confirmed the above observation by highlighting the outcome that the ethical frameworks more frequently used were balancing rights, maximising benefits as well as Christian values.

On informal reasoning approaches, it was noted that the experimental group students weaved greater complexity in their argumentation and there was increased rationalistic reasoning and less intuitive reasoning using the ethical frameworks. Also, the context of the socio-scientific issue determines the type of reasoning approach used. An intuitive reasoning approach seemed more prevalent in socio-scientific issues that call for more individualistic decisions to be made. Overall, in terms of developing ethical thinking, students using the five ethical frameworks demonstrated significant progression in perception and appreciation of socio-scientific reasoning from unaffected position to concern and informed judgment. In sum, the experimental group demonstrated a greater improved learning outcome and in the pre- and post-knowledge test, and this improved learning outcome was based on statistically significant results obtained from the quantitative data analysis.

On the point of a faith/ values framework in relation to ethical reasoning, it was noted from the students' responses in both comparison and experimental groups that intuitive reasoning can be influenced by religious convictions or religious knowledge. Faith can provide a basis for reasoning; and in some cases, faith could also take precedence over reasoning in opting for a more simplistic acceptance rather than a logical, rationalistic, step-by-step approach in reconciling differences in facts and reality. Analyses of the students' responses showed that how one makes a decision may only be partly conscious and could have been shaped by many factors from a Christian background; for example, one's upbringing, faith commitment, past experience and reflection.

Conclusion

This study argued that the use of ethical frameworks can be an effective means to explore socio-scientific issues. The implementation of such a pedagogical tool addressed some of the concerns of contemporary science education; that is, to develop critical thinking strategies with an emphasis that includes both the *affective* and the *cognitive* aspects in science learning. The use of ethical frameworks in socio-scientific education as a teaching and learning tool also reinstates the importance of incorporating *values* in science education, and establishes a tangible link between moral considerations and scientific literacy. The use of ethical frameworks in socio-scientific education has demonstrated an increase in the number of informal reasoning approaches utilised - primarily intuitive, rationalistic and moral (including faith/values).

The incorporation of faith values in the ethical frameworks confirmed previous research that there was the possibility that *other* concepts besides that of justice and fairness could be the key in determining how one judges what is morally right. The present research indicated that there is a wider range of problem solving strategies in making moral judgments, in addition to the reasoning processes described by cognitive developmental psychologists and educators. The present study also suggested that the allegiance to belief systems and ideologies can sometimes override the influence of one's own sense of fairness in making decisions of moral rightness. This is an important factor to consider when mapping out curriculum for moral education and socio-scientific education, and certainly bears implications for future values-based educational research.

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