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Life Sciences Teachers' Views on Teaching Socio-Scientific Issues in Genetics using an Inquiry Approach

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Abstract. The study sought to establish teachers' views about scientific inquiry in teaching genetics whilst addressing socio-scientific issues (SSIs). The argument was if teachers do not fully understand the holistic nature of scientific inquiry, it prevents them from using SSIs effectively to facilitate learners' understanding of abstract concepts. The study focused on genetics as a topic with SSIs and with abstract concepts difficult to present in concrete materials. Therefore, the paper aimed to learn about Life Sciences teachers' view in using scientific inquiry in teaching genetics whilst addressing socio-scientific issues. In an explanatory sequential mixed method research design, two questionnaires were administered to 100 Life Sciences teachers, to seek their views about scientific inquiry and understanding of socio-scientific issues respectively. Interviews were administered only to six teachers whose responses based on the analysis of data from questionnaires, were considered as informed, partially informed and naïve views. Lesson plans for selected teachers were analysed. The findings showed that the teachers were aware and appreciative of the inquiry-based approaches and socio-scientific issues embedded in genetics. The teachers however required extensive knowledge and skills on the procedures of inquiry that have to be employed when addressing socio-scientific in genetics. These findings inform teachers and teacher professional development programmes on the importance of context as the source of socio-scientific issues that tend to impact on learner understanding of concepts in topics such as genetics.

Keywords: genetics; scientific inquiry; Life Sciences; socio-scientific issues; teachers' views

1. Introduction

Learning of specific science concepts becomes meaningful and interesting to learners if it explains their life experiences (Kawasaki & Sandoval, 2020). A

deliberate use of scientific issues (socio-scientific issues) that require learners to engage in dialogue, discussion, and debate (Zeidler & Nichols, 2009) enables learners to engage with and understand abstract concepts. Previous studies have shown how teachers are constrained to address socio-scientific issues (SSIs) in their teaching because they view science as an objective body of knowledge free of values (Reis & Galvão, 2009); and some lack the pedagogical skills to deal with classroom discussions and debates that are stimulated by SSIs (Levinson & Turner, 2001). The lack of pedagogical skills was also noted by Marbach-Ad and Stavy (2009) who found that teachers struggle with connecting the values or morals engrained within learners during the teaching and learning of abstract topics to ensure holistic conceptualisation of the scientific content. It shows that the teachers lack an understanding of the nature of science (NOS) yet NOS is meant to show an epistemological stance teachers have.

Because several studies have focused on teachers' acceptance of SSIs and their views about SSIs (Akbulut & Demir, 2020; Nida et al., 2021; Parr, 2013), the current study focuses on teachers' views about the teaching of SSIs in genetics when using an inquiry approach. The argument is that whilst SSIs develop scientific literacy and bring the human aspect into science, i.e. its relevance and applicability in real life, the scientific inquiry approach affords the teachers the opportunity to engage learners in the construction of own knowledge without teachers imposing it on them. Scientific inquiry refers to the diverse processes through which science knowledge is produced and established as a result of the work of scientists (Hofstein & Lunetta, 2003; National Research Council [NRC], 2011). The integration of SSIs when teaching science requires innovation in selecting suitable teaching strategies to be employed (Foulk et al., 2020). To integrate SSIs, Foulk et al. (2020) designed a timeline activity in which science learners could use to determine how historical events have influenced the American people's perceptions of nutrition. Such an activity helps teachers to integrate scientific concepts with real life events which can be economical, political or social in nature and it develops learners' decision making in real life (Foulk et al., 2020).

In a study to determine whether specific SSIs could increase the connection between students, science and real-life problems, Vasconcelos et al. (2018) reported the use of inquiry-based learning wherein groups of students from Porto Santo in Portugal, solved a case of using sand and clay in skincare. In addition to attaining scientific concepts, the findings showed how the inquiry-based activity developed learners' collaborative, communication, and argumentative skills (Vasconcelos et al., 2018). In addition, Vasconcelos et al. (2018) pointed out that such inquiry-based activities made learners to be critical, autonomous and creative, which Foulk et al. (2020) considered as essential competences for citizenship in society. The present study argues that if teachers do not fully understand the holistic nature of scientific inquiry, it prevents them from using SSIs effectively to facilitate learners' understanding of abstract concepts. This is illustrated in the context of teaching genetics.

1.1 Purpose of study

Teachers' perceptions on the teaching of SSIs affect their understanding and implementation of the curriculum, and ultimately impact on the decisions they make during planning and preparation of their teaching (Ekborg et al., 2012; Sadler & Zeidler, 2005). The purpose of the present study is to determine how in-service teachers view the teaching of abstract concepts in genetics (a topic embedded with SSIs) using inquiry approaches to foster meaningful understanding of abstract concepts in learners. It is through inquiry that teachers' and learners' attitudes can be transformed to allow for higher order reasoning and to help teachers address any misconceptions in learners. Consequently, the study was guided by the research question: How do teachers view the use of scientific inquiry in teaching genetics, whilst addressing socio-scientific issues?

2. Literature Review

2.1 Socio-scientific issues in science teaching and learning

SSIs have been described as authentic challenges in society which are connected to science (Owens et al., 2019). The SSIs in science emanate from the natural phenomena that try to connect scientific knowledge with the societal knowledge in answering scientific questions (Amos et al., 2017; Ariza et al., 2014). SSIs originate from the affective domain that influences teachers' views when teaching topics or concepts that have a bearing on learner emotions, attitudes and values (Abeysekera & Dawson, 2015). These SSIs cannot be ignored in the Life Sciences classrooms because they are embedded in everyday life activities and experiences. They are derived from social challenges that have an effect on humans and ultimately on science knowledge development (Zeidler et al., 2005).

When addressed, SSIs engage learners in meaningful science learning as they require the use of evidence-based reasoning, and provide a context for understanding scientific information (Sadler, 2004; Zeidler, 2003). This is possible because learners develop a degree of moral reasoning when they discuss and evaluate ethical concerns before they make informed decisions in resolving real life problems (Zeidler & Nichols, 2009). SSIs in science are vastly becoming more prominent in effective science teaching and learning as a way of acknowledging that science should be contextual in nature (Reis & Galvão, 2009; Klassen, 2006; Rundgren & Rundgren, 2010). They are fundamental in the selection of activities or tasks to be done, which depends upon the teachers' decision in the selection of material to scaffold learning (Reis & Galvão, 2009). As early as 1993, Schein (1993) attested that children continuously learn from the environment to which they are exposed. Teachers' views about SSIs influence how science concepts are taught, conceptualised, and presented in the science classroom. Veugelers (2001) posited that SSIs are essential in developing learners into citizens that are critical thinkers, inquisitive about their environment, and are keen to solve societal problems. Addressing SSIs also relates the subject content to the reality of what happens or is experienced in the society, hence developing scientific literacy among learners (Kolsto, 2001; Millar & Hunt, 2002; Monk & Dillon, 2000).

Addressing SSIs when teaching science concepts is one thing, but learners' meaningful understanding is dependent on how the teachers scaffold knowledge

from the known (SSIs) to the unknown (science knowledge) (Bosser, 2018). Saunders and Rennie (2011) noted that there are immense socio-scientific dilemmas that affect Life Sciences topics like cloning, genetic engineering, genetically modified organisms (GMOs), genetic diseases and reproductive technologies that require learners to be more aware and develop skills in addressing these controversial topics. The controversy in these Life Sciences concepts emanate from SSIs which tend to generate conflict in the classroom (Hancock et al., 2019).

2.2 Teaching genetics, a topic with socio-scientific issues

Genetics is the science of hereditary transmission from one organism to another where traits are inherited (Batten & White, 2014). This genetic transmission can either occur in plants or animals in the form of similar or different traits due to parental attributes. Genetic concepts e.g. deoxyribonucleic acid (DNA) replication and mutations are abstract hence difficult to present in concrete materials. In a study carried out in South Africa, Kibuka-Sebitosi (2007) found that learners hold many misconceptions on genetics that relate to their lives. The sources of these misconceptions could also be pedagogical in nature in that the time between the presentation of some of the concepts in meiosis and those in genetics is too wide that learners forget and fail to make connections (Longden, 2010). Teachers should therefore use contextual materials that allow application and development of knowledge and inquiry skills that relate the concepts to learners' experiences and the environment they live in (Pukkillia, 2004; Sousa, 2017).

Addressing SSIs in genetics entails that the teachers should facilitate or guide the development of scientific knowledge through debates, discussions, and use of real life scenarios (Zeidler & Nichols, 2009) to avert misconceptions that may arise. An example is when teaching cloning; teachers can guide learners to identify advantages and disadvantages of cloning whilst considering socially misconstrued ideas. Engaging learners in a discussion, and asking questions related to values or morality of cloning may promote critical thinking skills in learners. Globally, genetics has been taught through the use of debates, arguments, discussions, and story reflection (Klassen, 2006; Zeidler & Nichols, 2009). Smith and Wood (2016) compared the teaching of genetics to undergraduate students in the past with those in the present and the findings revealed a shift from traditional methods of lecturing to more learner-centred methods. When involved, learners' interest, motivation and ultimately their achievement improve (Chu, 2008; Smith & wood, 2016). In a study to determine South African learners' understanding about genetics and inheritance at grade 11 and 12 levels, Kibuka-Sebitosi (2007) found that there was a clash between the learners' beliefs on inheritance and scientific perspectives. Such conflict arises when scientific knowledge is at loggerheads with learners' preconceived ideas and beliefs particularly in concepts such as albinism, GMOs and cloning. Teachers need expert skills to address such issues for instance Nyamupangedengu (2015) showed how teachers could use "trigger incidents" that stimulate discussions, thereby developing critical thinking and reasoning in learners (p. 152). Such teaching strategies enhance learners' inquiry skills as they get to ask more questions which lead to the development of higher meta-cognitive reasoning and understanding of abstract genetics concepts.

The teaching of topics with SSIs (e.g. genetics) using inquiry, plays a crucial role in bridging the gap that exists between content knowledge teachers and learners possess and the contextual knowledge in the society (Amos et al., 2017; Saunders & Rennie, 2011). Teaching SSIs in science topics therefore requires learner autonomy afforded by inquiry-based approaches, which Pedaste et al. (2015) described as involving questioning, exploration, experimentation, interpretation and making conclusions. Addressing SSIs in genetics may be daunting to teachers particularly in classrooms where there is a multiplicity of cultures for example in the South African context. Previous studies showed that teachers faced many challenges when teaching genetics because of the abstract nature of the topic, complex terminologies associated with genetics, and differences in learners' contextual knowledge (Saunders & Rennie, 2011).

2.3 Scientific inquiry as the conceptual framework

The present study is underpinned by the scientific inquiry as the conceptual framework. In school science, learners use inquiry approaches to understand how scientists investigate the natural world (Crawford, 2014; Penn et al., 2019). As learners enact science inquiry, they collect and analyse scientific data through observations for example, make conclusions, provide explanations for evidence and communicate their findings to others (Crawford, 2014).

The NRC (2011) and Next Generation of Science Standards for K-12, have advocated for the use of inquiry to develop metacognitive reasoning among learners while considering the contextual environment. According to Harlen (2014) and Ariza et al. (2014) the inquiry-based approaches help learners to acquire the necessary social problem-solving skills, which include questioning, identifying the problem, investigating, evaluating and hence developing analytical skills. This is possible because inquiry is a form of constructivist/interactionist approach (Dewey, 1996) that strives to develop learners cognitively and socially (Bryan & Keys, 2001).

The current study presupposes that teaching SSIs in genetics through the use of inquiry-based approaches, will go a long way in improving learner understanding. Such a process will embrace the moral and value system essential for the development of more creativity and innovation among learners (Sadler et al., 2004). Teaching using inquiry does not only involve experimentation in a laboratory but can include the use of other sources to evoke the rise of new questions in science that can then be solved in relation to various societal issues (Amos & Levinson, 2018; Galano et al., 2016; Sousa, 2017). Inquiry provides an opportunity for each individual learner to have different experiences, thereby catering for diverse attitudes, values, ethics, beliefs and epistemologies (Saunders & Rennie, 2011). The process may probably alleviate the problem raised by Levinson and Turner (2001) who noted that teachers find it difficult to teach science while addressing SSIs that affect learner understanding in the science classroom. In support, Klassen (2006) indicated that if contextual knowledge (SSIs) is incorporated in science teaching, it develops critical thinking in learners particularly when teachers use inquiry-based approaches and activities that holistically develop learners emotionally, socially, and in terms of the scientific

knowledge. Figure 1 illustrates how the use of inquiry approaches in addressing SSIs in genetics, can develop learners holistically.

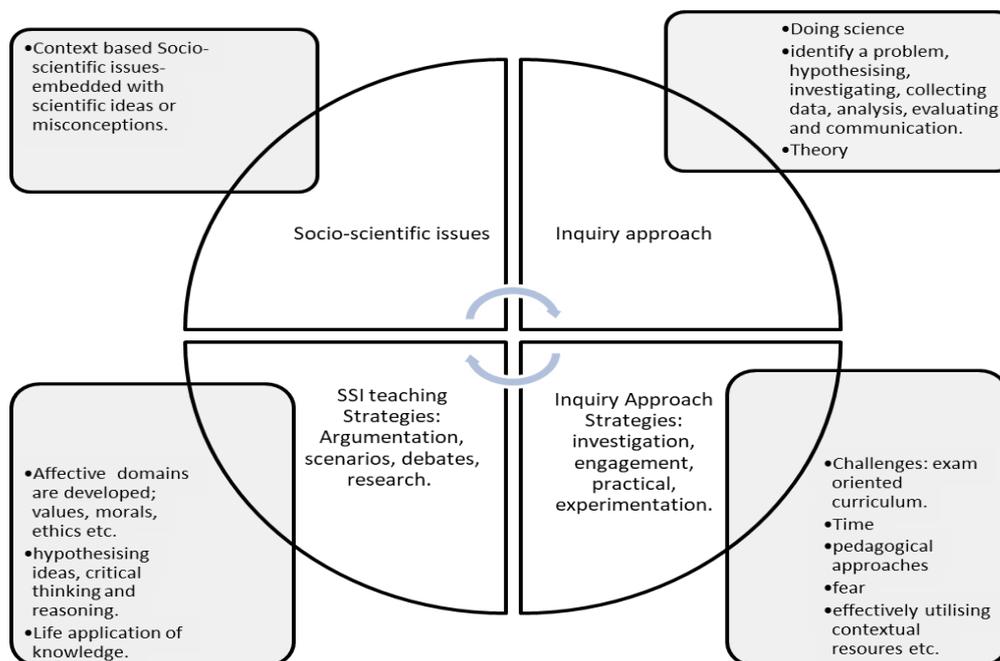


Figure 1: Holistic development through the blending of SSI and inquiry approach

The model in Figure 1 was developed by the researchers (authors of this article) using various literature sources (e.g. Ratcliffe & Grace, 2003; Hancock et al., 2019) to explain how SSIs in genetics can be addressed using the inquiry approach. The blending ensures the misconceptions emanating from the social contexts learners bring from their upbringing, can be addressed through inquiry practical investigations which enable deeper understanding of scientific concepts in learners (Zeidler, 2003; Ratcliffe & Grace, 2003). The use of inquiry approaches whilst addressing SSIs transforms learners' attitudes towards the subject and topic (transformation of the affective domain), which normally is an ignored area since most teachers focus on the cognitive domain.

The authors assume that an integration of SSIs in genetics teaching will enhance the development of morals, values and ethics in learners (Abeysekera & Dawson, 2015; Bryan & Keys, 2001; Klassen, 2006). The rationale is that the blending of inquiry and SSIs enables teachers to develop effective pedagogical approaches and cut the amount of time they spend in teaching a particular topic. By establishing how teachers view the use of scientific inquiry in teaching genetics, whilst addressing socio-scientific issues, the present study is a precursor to the development of teacher professional development programmes on the teaching of SSIs using inquiry approaches.

3. Methodology

The study is located within pragmatic paradigm where the world is viewed as both real and socially constructed (Morgan, 2014). It follows an explanatory sequential mixed method research design (Creswell, 2014) in which the researchers first collected quantitative data, analysed the data, and then used the results in formulating questions used in collecting qualitative data from fewer individuals through interviews (Creswell, 2014; Subedi, 2016). The design was suited to this study as the quantitative data on teachers' views about SSIs and inquiry approach was explained by some of the findings from qualitative data.

3.1 Selection of participants

From the Johannesburg high school Life Sciences teachers, a group of 100 teachers was randomly selected, 50 from township schools (poorly resourced) and 50 from suburban schools (well resourced). The schools had a pass rate below 60% in Life Sciences. In the context of South Africa where the study was undertaken, the differences between township and suburban schools is that in addition to differences in resource availability township schools have larger class sizes (> 45) compared to suburban schools (≤ 35) (Msila, 2009). It was important to determine these teachers' teaching patterns and approaches from the two contexts as this could have had an impact on learner performance. The sample was suitable for this study due to the high levels of diversity of teachers and learners in the schools in terms of language, values, ethnic, and cultural differences, which could influence the SSIs they held.

3.2 Data collection, instruments and analysis

3.2.1 Administration of questionnaires

To elicit teachers' understanding about scientific inquiry, only the first six questions of open ended questions of the Views of Scientific Inquiry (VOSI) instrument (Schwartz et al., 2008) (Appendix 1), were administered to the 100 in-service Life Sciences teachers. In addition, a questionnaire (Appendix 2), which sought the teachers' understanding of SSIs in genetics and their views about the teaching of SSIs using inquiry-based approaches, was administered. All questions sought open-ended responses from teachers, which ensured teacher autonomy in the reasoning and thinking, hence the teachers' responses were envisaged to be unbiased and reliable (Kothari, 2004). Both questionnaires were piloted first with 20 teachers who were not part of the participants and the results used to modify the clarity of the wording in the questionnaire items.

Data from both questionnaires were analysed using the VOSI rubric with a number of possible responses for each category: naïve- 1; partially informed- 2; and informed- 3. If the responses did not resonate with the accepted views, they were deemed as naïve and were allocated a score of 1. A response was awarded a score of 2 for the partially informed view category if it had some aspects or contradictory perspective in light of the desired answers. To score 3 for the informed category, the response had to correspond with the targeted aspect of scientific inquiry, socio-scientific issues or the teaching of socio-scientific issues using inquiry. The two researchers for the present study and a science education specialist engaged in prior validation of 33 participants' responses to the questionnaires by reading through the transcripts and scored the teachers' responses independently using the scoring rubric, then compared the scores assigned in order to establish inter-coder reliability (Leedy & Ormrod, 2014). By the end of this process the three independent coders, attained an inter-coder reliability above 80% agreement. The remaining 67 transcripts were then analysed by the researchers. The scores were then analysed using the IBM SPSS 26 software to generate descriptive statistics.

3.2.2 Administration of interviews

The results from the analysis of data from questionnaires were stratified into informed, partially informed and naïve views. A purposive stratified sampling technique was used to identify two teachers (one from township and the other from suburban school) from each stratum, and follow-up semi-structured interviews (Tongco, 2007), were administered to the six teachers individually. The interviews determined how the teachers' views influenced their instructional conceptions when teaching genetics whilst addressing SSIs using inquiry approaches. Qualitative data was essential in authenticating the data from the questionnaire responses given, hence making the data more realistic in nature to limit biases from some of the responses (Pluye & Hong, 2014). Interviews were audio recorded and transcribed verbatim.

3.2.3 Analysis of lesson plans

Six lesson plans from the six interviewed teachers were analysed to authenticate the information from the questionnaires and interviews. The teaching strategies, examples and activities planned for the lessons were analysed to assess teachers' willingness to address SSIs in the genetics concepts to be taught. Textual data from both interviews and lesson plans were coded using manual coding (Saldana, 2009). They were then categorised using the three scales that indicated teachers' views as naïve, mixed and informed.

3.2.4 Validity and reliability

The use of different data collecting methods triangulated data and illuminated the validity and reliability of the data as issues raised in the questionnaires were authenticated by what the teachers said in the interviews and what they wrote in their lesson plans (Abeysekera & Dawson, 2015). As such, the views teachers held about scientific inquiry in teaching genetics, a topic embedded with SSIs were explicitly determined. Any identified discrepancies required administering a second round of interviews to ascertain them and only one participant warranted

a second round of interviews. Ethical considerations were adhered to as stipulated by the Research Ethics Committee.

4. Results

The results on the teachers' views about scientific inquiry in teaching genetics while addressing socio-scientific issues are presented using three subheadings, which are: Teachers' understandings of scientific inquiry; Teachers' understandings of socio-scientific issues; and Teachers' understandings of addressing socio-scientific issues embedded in GMOs a genetics concepts embedded with SSIs.

4.1 Teachers' understandings of scientific inquiry

There were more teachers who held informed views about what scientific inquiry is (97.7%) and knowledge of how it could be used in teaching genetics (90.9%) compared to those who held informed views about the sequence of scientific steps (31.8%). The teachers who indicated that the inquiry approach requires a series of sequential steps that cannot be changed despite the changes in the contextual knowledge acquired (68.2%), showed a rigid way of doing scientific inquiry. This was categorised as naïve because methods and sequencing of steps depend on the aims and objectives investigated at a particular time. These teachers did not consider that scientific inquiry steps can resume at any step depending on the context that is being investigated. For example, a scientist can start by analysing already collected data and make inferences. Table 2 shows an example of an analysis of some of the teachers' responses to the question: If several teachers in different contexts ask the same questions and use the same procedure, will they arrive at the same conclusion?

Table 1: An example of analysis of teacher responses

Teachers' pseudonyms	Responses	Teachers' scored views	Reasons for the scores
Curtis	Yes, the principles of scientific inquiry are the same hence the outcome will be the same.	1	Naïve view. The teacher did not consider the influence of the contextual knowledge influences.
Tebogo	Use of same questions using the same procedure therefore conclusions should be the same.	1	Naïve view. The teacher's response lacks consideration of individual views, contexts or the resources that can give different results.
Neo	I don't think so because they are asking the same question coming from different contexts	3	Informed view because the teacher is aware of the influence emanating from different contexts
Theodore	Yes but it depends on the knowledge and skill of the teacher	2	Partially informed view because the teacher's knowledge and skills are not the only things that affect the development of contextual knowledge. Materials and learner knowledge influence the outcomes.

The finding that some teachers have partially informed and naïve views has implications for the manner in which they design scientific inquiry activities for their learners. These teachers could give learners rigid steps to follow without considering learners' autonomy.

4.2 Teachers' understandings of socio-scientific issues

Teachers' views about socio-scientific issues embedded in genetics are important as teachers' views influence the manner in which they teach the concepts. Table 2 presents the distribution of teachers' views about each question.

Table 2: Teachers' understandings of socio scientific issues in the topic albinism

	Naïve %	Partially informed %	Informed %
1. Learners' environment influences content and material taught in genetics	15.9	0	84.1
2. The topic genetics considers learners' diverse context	18.2	25	56.8
3. Instructional time should be spent teaching SSIs	11.4	9.1	79.5
4. Scientific inquiry is the best way to teach SSIs	6.8	13.6	79.5
5. How albinism can be taught in a class where there is an albino child	9.1	11.4	79.5
6. Do you think the affected learner (learner with albinism) will take offence? If so how can you minimise the discomfort of the learner(s)?	15.9	4.5	79.5
Average	12.9	10.6	76.5

Table 2 shows that teachers held more informed views about socio-scientific issues (average of 76.5%) compared to their informed views about scientific inquiry (average 72.73%) in the previous section. This could be because socio-scientific issues are engrained in their everyday life experiences as members of the society. They are therefore cautious of them as they struggle in their classrooms when dealing with such issues. There was however a high percentage (43.2%) of naïve and partially informed views in response to question 2 compared to all the questions. The question required teachers to share their views on whether the South African Life Sciences curriculum considers learners' diverse/multiplicity of context with regard to the topic genetics. A point to note is that in one of its specific aims the curriculum stipulates the importance of "understanding of applications of Life Sciences in everyday life" (DBE, 2011, p. 13). In the content area the curriculum only refers to consequences of abnormal meiosis in the case of Down Syndrome and harmful mutations in the case of conditions such as albinism. Nothing is however mentioned about how the teachers can navigate such sensitive issues in the classroom. Hence the curriculum is silent about how the teaching of SSIs should be implemented in the classrooms, leaving individual teachers to identify the suitable strategies and activities by themselves. In the interviews the teachers bemoaned the insensitivity displayed by the Life Sciences curriculum when dealing with diversity in the classroom. An example given was that the curriculum is silent about how teachers should teach the concept albinism considering that there could be learners whose family members are albinos and let alone when there is a learner in the classroom with the condition. Some

teachers pointed out that genetic disorders such as albinism are very sensitive and are controversial concepts of genetics to teach. An example is depicted by one participant who said, "I am a human being and in as much as I want to effectively teach these concepts, there are things that cannot be discussed due to community beliefs about albinism."

Four teachers who were less experienced (less than five years' teaching experience) and two teachers with 11 to 20 years' experience, displayed naïve views to the question: *There is an albino child in your Life Sciences class, how would you approach the concept of albinism in that class?* The teachers' responses were that it is important to ask the 'affected' learner to explain their condition to the rest of the class. This was categorised as a naïve perspective due to lack of respect and consideration of the individual learner or the psychological, emotional or social impact this kind of action could have on the learner. One of the teachers pointed out in the interviews that how a teacher introduces and engages learners when teaching controversial topics makes a difference. The teacher said, "It's the way the teacher does it, you have to be sensitive and you can never use a child in a class as an example." Three of the interviewed teachers mentioned the importance of engaging learners in research, discussion, debate and even argumentation when teaching a controversial topic so that learners can share their view points. Such activities help learners to search for information, engage with ideas from other learners and at the end determine the most appropriate explanation to what they will be dealing with. One participant gave an example of beliefs learners bring to the Life Sciences classroom which the teacher alone cannot tackle. She said that several of her learners once said, "Ma'am do you realise that the spirits or souls of albinos don't go anywhere after death, they get caught up in the spiritual world." Another participant mentioned that her learners thought that albinism is a curse on the parents of such a child. Given such beliefs, it means learners with albinism will be isolated and stigmatised. Such findings show that there are many SSIs embedded in the topic genetics. If such concepts are not explored using the appropriate methods, learners may remain with these naïve ideas, which can be very dangerous particularly in today's society where there is a lot of discrimination and violence against certain groups of people.

4.3 Addressing socio-scientific issues using inquiry approach

The questions given to teachers were meant to assess their views on how socio-scientific issues could be addressed. From the teachers' responses, one could deduce their orientation with regard to the use of inquiry-based approaches in their teaching of the concepts as they explained how they handled different ideas on genetics brought to the classroom. Table 3 shows the distribution of teachers' views about addressing socio-scientific when teaching concepts on genetically modified organisms (GMOs). The teachers were responding to questions asked in the SSIs questionnaire about scenarios of two groups of researchers. One group of researchers presents the benefits of GMOs in terms of quality food taste and disease resistant crops hence saving on pesticide usage. The other group of researchers insists that there have not been conclusive studies to show the long-term effects of GMOs on both plants and animals.

Table 3: Teachers' understandings on the teaching of GMOs using inquiry approach

Item	Naïve %	Partially informed %	Informed %
1. How would you explain to the learners the differences in the claims made by the two groups of researchers on GMOs?	6.8	29.5	63.6
2. One teacher decided to task learners to record the views of their community members about the GMOs and compiled a report. Is this a scientific inquiry?	18.2	6.8	75
3. Do you think that the strategy recommended above is applicable in South African context? Why and why not, give reasons and examples.	59.1	6.8	34.1
4. Is it important to discuss ethical issues associated with the process of genetic engineering with the learners? Explain your answer.	4.5	-	95.5
5. If learners bring in their conflicting views in the classroom, would you consider the discussion and analysis as scientific inquiry? Explain your answer.	4.5	6.8	88.6
Average	18.6	9.98	71.4

Whilst the majority of the teachers displayed informed views about the teaching of GMOs (an average of 71.4%), there was quite a number (59.1%) who held naïve views about the applicability of the suggested teaching strategy in the South African context. The strategy required learners to interview and record community members' views about GMOs. In the interviews when asked about the usefulness of such a strategy, most of the teachers were quick to argue that people in communities were not well informed about GMOs, hence learners would not collect reasonable information. It shows that the teachers do not have confidence in the level of knowledge community members possess, which is unfortunate because teachers are making decisions based on assumptions. Such attitudes undermine the role the community plays in the education of learners. Another point is that these teachers display naïve views about research because by carrying out an inquiry, you do not expect to get only the results you expected and that even from unexpected responses, learners can obtain valuable information.

Most teachers held informed views on the advantages and disadvantages of genetic engineering while citing examples such as "the need to cater for the demand in food production, genetic engineering causing some diseases, genetic engineering having negative effects on health, and also causing genetic mutation of plants." Only a few mixed views were noted in relation to the curriculum, when answering the question on whether "the strategy of teaching socio-scientific issues using inquiry is applicable in South African context." The responses included the idea that the strategy depends on the society; the knowledge on curriculum content intensity; time frames; and assessments. The issues about diversity of societal knowledge were not taken into consideration.

Based on the analysis of teachers' lessons, the teachers held informed views about the methods used in teaching SSIs and their application in teaching and learning. They gave examples like the use of videos, technology or internet in the Life Sciences classrooms. Teachers however cited the availability of resources, sizes of the classrooms, experience, technology, support systems from home, school or community, learners' interests and attitudes, as important.

During interviews teachers had various views when asked the question: *do you think that the methods used in teaching SSIs, should be universal across the country?* Those who showed informed views argued that because there are different teaching and learning environments, teaching should cater for the different contexts by using examples familiar to the learners. For instance, one of the teachers said, "If teaching at a school in the coast, then use examples from the marine world." Those who opted for universal teaching methods argued that learners write similar examinations at the end of the year, which do not provide for the different contexts in which learners are taught. Such a justification shows that the teachers do not realise that the use of contextual materials allow learners to apply and develop knowledge and inquiry skills that relate the concepts to learners' experiences and the environment they live in. One of the teachers, indicated that learners have inquisitive minds therefore, it is imperative that learners be engaged in inquiry activities to ensure knowledge acquisition. Some of the 'prerequisite characteristics' of a Life Sciences teacher mentioned by the teachers included: being an inquisitive teacher; having the ability to elicit learners' thought processes before teaching any content; and considering diverse learners' context. The teachers' responses are aligned to the scientific inquiry-based approaches.

Other teachers pointed out that scientific inquiry engages learners in discovering knowledge by themselves. The teachers justified this particularly when teaching controversial topics that are embedded with socio-scientific issues where learners bring in different ideological thoughts and practices based on their upbringing. One teacher pointed out that, "There are SSIs that when presented from the teachers' perspective, might have an impact on some of the learners' rights within the classroom". The teacher suggested indulging or engaging learners in learner-centred discussions, such as argumentation, giving learners an opportunity to debate issues and explore their thought processes, whilst the teacher acts as an observer and facilitator or guide. One participant reiterated, "Learners brainstorm on these socio-scientific issues and get to understand the underlying scientific ideas inherent in those issues". One of the teachers however cautioned that there is need for the teacher to be attentive and be wary of learners who might take issues personally and get offended in the teaching and learning process.

5. Discussions

The majority of teachers had informed views about addressing socio-scientific issues in the topic genetics. This was shown in an example where 84.1% of the teachers thought that learners' environment influences the content and material that can be taught in genetics. This is attested by the majority of teachers (95.5%) who held informed views about the importance of discussing with the learners

the ethical issues associated with the process of genetic engineering. Such findings are supported by previous researchers who noted that the teaching of topics embedded with SSIs using inquiry plays a crucial role in bridging the gap that exists between content knowledge of the teachers and learners with that of contextual knowledge in the society (e.g. Amos et al., 2017; Saunders & Rennie, 2011). It is through inquiry that teachers' and learners' attitudes can be transformed to allow for higher-order reasoning as SSIs are fundamental in developing conceptual understanding, particularly in the topic genetics (Schalk, 2012).

Whilst the majority of the teachers displayed informed views about the inquiry-based approaches, there were some teachers who showed naïve views. For instance, when asked if they would consider discussion and analysis as scientific inquiry when learners bring in their conflicting views in the classroom, the teachers who showed naïve views indicated that they would not consider it at all. They viewed discussion and analysis as intrusive methods particularly when dealing with sensitive issues. Such teacher sentiments are shared by Juntunen and Aksela (2013), who found that inquiry approaches are the most effective methods but the main issue is on how teachers use them in teaching abstract topics like genetics to scaffold learning. These teachers' views could be because of the context in which they find themselves in for instance Pope (2017) pointed out that issues of ethics, morality and religion play an role in the pedagogical practices of teachers in the classroom.

The majority of teachers displayed naïve understanding about the use of inquiry approaches in teaching GMO, a concept with SSIs. They indicated that engaging learners in recording the views of their community members is not a scientific inquiry. This indicated that teachers' reasoning on inquiry in teaching genetics is based on testing in a laboratory to prove an idea without developing critical thinking and reasoning (Setty & Kosinki-Collins, 2015; Tsai, 2018; Amos et al., 2017; Ariza et al., 2014). There were a few teachers who were sceptical about using inquiry approaches such as engaging learners in an argumentation when addressing controversial concepts in genetics thereby denying learners an opportunity to make informed decisions. This defeats the affordances of inquiry-based approach which can develop metacognitive critical thinking and reasoning in learners (Crawford 2014; Balim & Ozcan, 2014). The teachers' naïve views are of concern considering that teachers' views on the moral challenges associated with teaching genetics may affect the teaching of these abstract concepts (Zeidler & Nichols, 2009). It is however important to consider these teachers' naïve views as in some cultures, argumentation is considered confrontational which Hewson (2015) considered unAfrican as it goes against the African values of communal sharing and respecting of others. It could be that these teachers felt that argumentation goes against the essence of harmony in their science classrooms.

When asked about their thoughts on whether the teaching of socio-scientific issues should be universal across the country, teachers with informed views argued for contextualised teaching. The findings from these teachers are in line with the previous studies by Abeysekera and Dawson (2015), Sousa (2017) and Kibuka-

Sebitosi (2007) who found that the use of contextual knowledge that learners bring to the classroom, fosters metacognitive reasoning among learners. On the other hand, the teachers who held naïve views argued for universal teaching since learners would write the same examinations at the end of year. In this particular case, teachers showed a lack of understanding on how controversial issues can be handled in the classroom and is likely to negatively affect learners' acquisition and understanding of scientific knowledge (Setty & Kosinki- Collins, 2015).

The teachers were forthcoming when it comes to teaching strategies that foster inquiry-based learning in the Life Sciences classroom particularly when it comes to giving learners autonomy to engage with their thought processes. Teachers indicated the utility value of inquiry strategies when addressing socio-scientific issues and brainstorming on controversial concepts such as albinism and GMOs. The strategies mentioned included learner-centred discussions, use of argumentation and debate whilst the teacher acts as an observer and facilitator or guide. This shows how scientific inquiry is multifaceted in nature and how it has become one of the most advocated approaches for science teaching and learning in today's classrooms (Harlen, 2014; Ariza et al. 2014; Lederman, Lederman & Antink, 2013).

6. Pedagogical Implications and Recommendations

The study sought to establish Life Sciences teachers' views on the use of scientific inquiry in teaching genetics, whilst addressing socio-scientific issues. The findings showed that teachers' limited understanding of the holistic nature of scientific inquiry prevents them from addressing SSIs effectively to facilitate learners' understanding of abstract concepts in genetics. Whilst the study found that teachers held informed views about what scientific inquiry is and knowledge of how it could be used in teaching genetics, they however showed a limited understanding on how the sequence of the steps in scientific inquiry could be implemented in the classroom. As a result, teachers were not convincing in their reports on how SSIs in genetics could be taught using an inquiry approach. From a practitioner's point of view, teachers' views about socio-scientific issues in some science topics should be taken into consideration as views influence the manner in which teachers teach the concepts. Failure to consider teachers' views may result in teachers' apathy in utilising pedagogical strategies which engage learners in the desired analytical and critical thinking. Teachers therefore require professional development forums where they interrogate their views and practices when teaching controversial topics with the guide of teacher educators and curriculum specialists.

Future studies should extend the study to include learners' views and also observe the teachers' practices whilst they engage learners in inquiry activities in order to address socio-scientific issues, which are not only embedded in the topic genetics but other topics as well. The study contributes to a body of knowledge on teachers' perspectives on the strategies that foster inquiry-based learning that give learners autonomy to engage with their thought processes when addressing socio-scientific issues and brainstorming on controversial science concepts.

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Appendix 1: Views of Scientific Inquiry (VOSI) instrument (Schwartz, Lederman & Lederman, 2008)

1. What types of activities do scientists do to learn about the natural world? Be specific about how they go about their work.
2. What scientists choose to study and how they learn about the natural world may be influenced by a variety of factors. How do scientists decide what and how to investigate? Describe all the factors you think influence the work of scientists. Be as specific as possible.
- 3 (a) Write a definition of a scientific experiment?
A scientific experiment is.....
b) Give an example from something you have done or heard about in science that illustrates your definition of a scientific experiment.
c) Explain **why** you consider your example to be a scientific experiment.
4. A person interested in birds looked at hundreds of different types of birds who eat different types of food. He noticed that birds who eat similar types of food, tended to have similar shaped beaks. For example, birds who eat hard shelled nuts have short, strong beaks, and birds who eat insects from tide pools have long, slim beaks. He concluded that there is a relationship between beak shape and the type of food birds eat.
a) Do you consider this person's investigation to be scientific? Please explain why or why not.
b) Do you consider this person's investigation to be an experiment? Please explain why or why not.
5. Some people have claimed that all scientific investigations must follow the same general set of steps or method to be considered science. Others have claimed there are different general methods that scientific investigations can follow.
a) What do you think? Is there one scientific method or set of steps that all investigations must follow to be considered science? Circle one answer:
 - Yes, there is one scientific method (set of steps) to science.
 - No, there is more than one scientific method to science.

If you answered "yes," go to (b) below.
If you answered "no," go to (c) below.
- b) If you think there is one scientific method, what are the steps of this method?
c) If you think that scientific investigations can follow more than one method, describe two investigations that follow different methods. Explain how the methods differ and how they can still be considered scientific.
6. a) If several scientists, working independently, ask the *same question* (for example, they all want to find out what Oregon looked like 10,000 years ago, or what the structure of a certain protein is), will they necessarily come to the *same conclusions*? Explain why or why not.
b) Does your response to (a) change if the scientists are working together? Explain.

Appendix 2: Socioscientific Issues (SSIs) Questionnaire

1. Teachers understandings about Socioscientific issues

- 1.1 Is genetics a topic with socio scientific issues that can be experimented in science or not? Explain your answer.
- 1.2 Give examples of SSIs embedded in genetics.
- 1.3 How do learners handle such issues in the classrooms?

- 1.4 How do you handle any differences of opinion between what learners bring to the classroom regarding issues on genetics?
- 1.5 Do you think teaching the topics genetics in South African Life Sciences considers learners' diverse/multiplicity of contextual knowledge. Explain your answer.
- 1.6 Why is it important in South African schools to cater for diverse contextual knowledge in schools?
- 1.7 As a teacher, how would you teach the topic DNA replication to your learners?
- 1.8 Which effective teaching strategies would you recommend in developing content continuity from grade 10 -12 when teaching genetics?

2. Teaching SSIs using scientific inquiry approaches

- 2.1 Do you think learners' environment influences the content and material that can be taught in genetics? Give a reasons.
- 2.2 Do you think teaching the topic genetics in South African Life Sciences considers learners diverse/multiplicity of context? Explain your answer.
- 2.3 Do you believe it is important to spend instructional time in your science classroom to teach learners about SSIs? Give reasons.
- 2.4 If you think it is important what do you think is the best way to teach SSIs embedded in the topic genetics? Give examples of approaches.
- 2.5 There is an albino child in your Life Sciences class, how would you approach the concept of albinism in that class?
- 2.6 Do you think the affected learner (learner with albinism) will take offence? If so how can you minimise the discomfort of the learner(s)?

3. Genetic Engineering: Think of the pros and cons

GMO foods are genetically modified organisms that have had new genes from other organisms added to their existing genes. Common genetic modifications include: adding antibacterial genes to plants, introducing genes that make the organism bigger or stronger, making new foods by adding genes from existing foods, and adding animal genes to plants and vice versa.

Some researchers claim that GMO foods' benefits are better food quality, taste, and disease -resistant crops so that we have higher yields and more efficient production. GMO's allow farmer to skip steps in the production process, like spraying herbicides and pesticides, because the crops are already resistant. In some crops, they claim the foods are modified to contain additional vitamins and minerals.

Another group of researchers claim that there has not been enough testing of GMOs and no real long-term testing to detect possible problems. Another problem is allergic reactions; genetic modification often mixes or adds proteins that were not indigenous to the original plant, causing new allergic reactions to the human body. Another risk is that the modified genes may escape into the environment.

- 3.1 How would you explain to the learners the differences in the claims made by the two groups of researchers?
- 3.2 One teacher decided to task learners to record the views of their community members about the GMOs and compile a report. Is this a scientific inquiry? Explain your answer.
- 3.3 Do you think that the strategy recommended above is applicable in South African context? Explain your answer.
- 3.4 Is it important to discuss ethical issues associated with the process of genetic engineering with the learners? Explain your answer.
- 3.5 If learners bring in their conflicting views to the classroom, would you consider discussion and analysis of those views as scientific inquiry? Explain your answer.