Critical Reflection in Science Teaching and Learning: Crossing Borders into Western Science

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Abstract  Critical reflection enables humans to come to an awareness of how ideologies shape beliefs and practices that justify and maintain global economic and political inequity, explaining how subjugated people get convinced to embrace dominant ideologies as always being in their own best interests. Cultural change and adjustment is imminent in Africa as the waves of globalization sweep through, and science teachers need to develop correct frames of thinking to make sense of science teaching and learning. Serving and prospective teachers need to construct methods and purposes which reflect their own lived experiences and rationales for professionalism. This paper reports on a research study that sought to demystify western science through critical reflection, encouraging developing country cultures to use the science as their own tool for cultural progressiveness. It discusses the value of engagement by science educators and learners from non-western backgrounds in serious intellectual dialogues concerning their classroom practice on one hand, and their own feelings and thoughts about this practice gained from previous learnings and experiences, on the other. The paper draws from a qualitative case study carried out in a high school biology class in Zimbabwe. Insights from this study underscore the gains to science teachers and learners who engage themselves in self-initiated personal and methodological reflection on their pedagogical encounters. The microcosm of learnings from such reflection should promote transferrable learning to address short and long term life goals including personal welfare, ambition, heritage, and destinies of future generations.

Keywords: critical reflection, western science, student negotiation, personal relevance, transferable learning

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1. Introduction

Today’s average non-western learners in developing countries are confronted by social and environmental situations that are becoming increasingly complex compared to their western counterparts. Although non-western nations such as Zimbabwe get exposed to a variety of western and global influences from time to time, sections still maintain largely their traditional cultural outlook that, viewed through the lenses of pro-western civilization, is regarded as ‘backward’. Not only that, even in the eyes of impartial judges and some Africans themselves, the African culture is indeed backward because it has failed to produce endogenous sustainable and competitive solutions to basic human development challenges so crucial for survival in modern times [1], thus inviting renewed calls for the continent’s re-colonisation [2].

While visibly embracing and enjoying the attractive and irresistible products of western science and technology, some influential sections of Zimbabwean society still strongly advocate for the perpetuation of traditional ways of living, fearing becoming consumed into powerful alien cultures. It is, however, debatable if such advocacy is a sincere push for uplifting living standards of the common citizens rather than for personal self-fulfilment. This puts the helpless citizens in buffer zones between tradition and westernization. For instance, a good number of primary and secondary school students and teachers in remote areas have a taste of high-tech exposure through operating electronic gadgets, thanks to affordability of gadgets and donations. Such students and their teachers live in two worlds, their home connected to tradition, and their school and workplaces connected to western culture, incorporating science, computers and technology. It has been observed that some Asian countries have successfully blended their cultures with western science and technology without necessarily becoming totally westernized overnight, demonstrating that energies spent pushing back westernization could be diverted to finding worthwhile compromises, adjustments, and adaptations. Because western science is deemed the best global tool for human development, African systems of thought are considered unscientific and non-progressive.
When teaching students from modern African backgrounds (cultural border-crossers) the question is asked, do teachers reflect fully on both the opportunities and threats of being in such a scenario? Or are the teachers themselves victims of the very same problem? It is suggested that critical reflection and negotiation of socialization processes is crucial for moulding citizens who have the ability to influence their short and long term futures locally in the face of unprecedented social change globally, and the science classroom is a fitting starting point. Globalization and the virtual melting of borders make it very difficult to maintain a pure untainted system of traditional thinking and practice, particularly if the system trivializes science and the scientific method, and confers less benefits compared to its growing competitor.

An epistemology of education such as critical constructivism offers educators a lens with which to view and reflect on their own classroom practice, with the ultimate aim of improving the process and maximizing gains for the learners. Constructivists contend that scientific knowledge itself is imperfect and imperfectable [3]. Knowledge (including science) is tentative, and ways of constructing knowledge or inquiring about it need not be restrictive. The learner's ability in negotiating for meaning of phenomena is shaped by their cultural background and experiences. An individual's culture influences the individual's interpretation of their surroundings and their notion of reality and truth [4].

But students learn and master science not in exclusion to their other aspects of life, they integrate it into their social and emotional activities and life encounters. [5] advocate for a critical science education, one that not only prepares young people to be "...well-informed and discerning personal users of science in their daily lives", but also one that "...empower(s) students of science, through critical reflective thinking, to understand the enculturing nature of the science curriculum framework governing (and perhaps unduly restraining) their learning and their agency as learners." Students must be rid of the hidden dangers of the science curriculum framework governing (and perhaps unduly restraining) their learning and their agency as learners." Students must be rid of the hidden dangers of science in this era where science is gradually being thought of as "imperfect knowledge" [3]. Science does not guarantee solutions to threats of war and conflicts, cybercrimes, cultural degeneration, fraud and corruption, over-individualization, and general irresponsibility [6].

1.1. Critical Reflection

Teacher critical reflection in the learning, teaching and action research domain is important in today’s fractured but changing world. Teachers enrich their experience gradually and incrementally, and in the process pass the skills of reflection to their learners. At best, critical reflection and creative capability enhance transformational and lifelong learning skills, such as complex problem solving, communication, collaboration, vision building, and lifelong trans-generational action learning [7]. Critical self-reflection is the dimension involving questioning one's own assumptions, presuppositions, and perspectives allowing individuals to reassess or alter existing life structures. Among students, critical self-reflection is an opportunity to retreat summarily from their routine learning experiences and engage in deeper and more meaningful learning, reflecting seriously on the effect and source of their own assumptions, positioning, feelings, and behaviour [7]. High school leads to university for a sizeable number of these students, who will need to reflect on challenges such as moving from instructor-based learning to a more self-directed, independent learning style, and negotiating a transition to deep learning as a pre-requisite for academic achievement [7]. This is the ideal model for life and continuity of life among humans.

The central focus of this research study was to contribute to the attainment of quality goal-directed secondary school science teacher education in non-western developing Zimbabwe. Serving science teachers have a diversity of professional qualifications, orientations and motivations. This is in the light of a paucity of deliberate staff development programs or other efforts for such teachers to share challenges, experiences and aspirations. Behind this diversity lie some differences in teachers' understanding of learning theory and, subsequently, differences in their perceptions and practices of teaching. This paper addresses two questions:

1. What indications are there of internal dialogue and self-critiquing among secondary school science teachers in Zimbabwe?
2. How do the teachers and their students perceive the learning environment in their science classes in terms of personal relevance of subject matter and the practice of student negotiation?

1.2. Western Science for Non-Western Learners

[8] observes that few attempts have been made in the research relating to concept development in adolescent students "to understand how a non-western student might better learn science, a discipline which has been largely imported from foreign cultures" [8]. Non-western cultures have their own languages, traditions and myths which govern their perception of natural phenomena. They have their own "world-views", that is, beliefs about the world that support both common-sense and scientific theories [9].

1.3. Personal Relevance

Often in the past and the present, science teaching and learning has been directed towards gathering of objective facts and ideas. Students were taught to accept what they were told even when they could not see the relationships or the usefulness of the things they learn to their lives and to the social world outside the classroom. This is not to say that everything learnt in class should immediately and directly be mapped back to everyday life. An opportunity is missing that permits students to reflect on what they are learning about, to engage in a discursive activity that challenges [students] to reflect critically on [their] scientific knowledge or on the usefulness of that knowledge in the social world beyond the classroom [10].

Students have their own points of view about many objects and ideas that they encounter. Such points of view need be sought and valued, even when they may appear at first rudimentary and wayward. The classroom environment remains manageable despite differing points of view because discipline emanates mostly from the individual as teachers and learners share leadership roles. …..
teachers must focus on instructional goals rather than functioning primarily as disciplinarians. ... In order to promote autonomy and prevent an overbalance of heteronomy, constructivist teachers consciously monitor their interactions with children [11].

1.4. Student Negotiation

Students need an environment in which they can disclose and discuss their feelings. This is not simple in the normal classroom where the teacher is concerned about completing the syllabus with all thirty-plus students whose feelings matter. The diversity of opinions that can arise from a statement like: "How do you feel about our recent study of genetics?" or "What further related topics do you want us to talk about in future lessons?" often threatens the teacher who then resorts to spoon-feeding, dictating content, sequence and schedule of learning.

2. Methodology

The research paradigm adopted in this study is the case study using mixed methods, dominantly qualitative [12], and described as, "...multi-method in focus, involving an interpretive, naturalistic approach to its subject matter" [13]. This method facilitated data triangulation, producing a neat balance between the subjects' and the researcher's viewpoints. Non-participant observation, questionnaires, individual interviews and focus groups were used in a triangulation process to gather rich data from a single biology class so as to produce a "thick description" [12]. Data collected at the beginning of fieldwork through questionnaires was briefly analysed and used to generate new but connected questions and information for further observations and interviews (hermeneutic circles) in an explanatory sequential mixed methods design [14,15]. The analysis of data was an in-built, continuous process beginning during the fieldwork (fieldwork analysis) and proceeding beyond it (post-fieldwork analysis). For example, a popular response in the questionnaires would be followed up in class observations and interviews for clarification, confirmation or disconfirmation.

The main instrument for the smaller quantitative component was the re-visited teacher and student versions of the revised Constructivist Learning Environment Survey (CLES) [16]. The instrument has 6 items each on personal relevance and student negotiation, and uses a 5-point descending order Likert scale featuring the responses: almost always, often, sometimes, seldom, almost never for positively framed statements. The student version of the CLES was used in the main study with a lot of help being given to students with regard to language, including translating some items to vernacular where necessary. Interview and focus group question guides, as well as observation schedules were also used for the qualitative data phase.

Following a few weeks of preparation, the data collection commenced with the administration of the questionnaire to the purposively selected teacher and her class of twenty. After an analysis of the responses, and the identification of respondents of special interest, a focus group consisting of the teacher and four students was conducted, followed by individual interviews with five randomly selected students and the teacher.

3. Results and Discussion

3.1. Teacher and Class Background

Sipho (not her real name) is an indigenous African biology teacher in a coeducational government secondary school in a middle-income suburb in Bulawayo, Zimbabwe. This year, she teaches general science to four junior classes, and biology to one senior Advanced (A) Level class. She was observed for one week teaching this senior biology class of indigenous African students comprising twelve boys and eight girls aged between seventeen and nineteen.

Sipho had indicated during our initial preparatory meeting that she was willing to participate in the study mainly to learn about some science pedagogy since, she acknowledged, she had no professional teaching qualification. With three years of teaching experience behind her, she has only a discipline-specific qualification, a Bachelor of Science in Microbiology. She has, in the past, attended a few in-service seminars on the teaching of science organized by the local universities and the Ministry of Primary and Secondary Education.

3.2. Conceptualising Personal Relevance of Learning and Student Negotiation

Sipho's responses to the CLES indicate that, from her perspective, she teaches biology very often to make the subject personally relevant to her students, relating to their out-of-the classroom world, and she almost always supports student negotiation in her class (see Table 1 and Figure 1).

![Table 1. Student (N=20) and their Teacher scores on Perceived form of CLES](image)

| Respondent       | Personal Relevance | Student Negotiation | Maximum |
|------------------|--------------------|---------------------|--------|
| Teacher          | 27.00              | 29.00               | 30     |
| Students (mean score) | 22.85              | 25.95               | 30     |

Responses from the twenty senior biology students show that they feel their class utilizes a high degree of student negotiation, whereas they perceive the lessons as being only sometimes personally relevant. Student individual scores (see Figure 1) for personal relevance range between 18 and 28 (sometimes to almost always), and for student negotiation they range from 19 to 30 (sometimes to almost always), with five students reporting that student negotiation occurs almost always. The spread of the individual scores shows that the students are more agreed in their perceptions for personal relevance than they are for student negotiation. In general, the students' mean scores for both scales are lower than their teacher's, a common finding in studies of perceptions of classroom environments [17]. However, there is a parallel perception in that, in general, both students and their teacher perceive student negotiation to occur more frequently than personal relevance.
3.3. Displays of reflective Conceptualisation and Practice

Sipho often started her senior biology lessons by leading a general discussion on a topical issue, for example, something that came up in the media lately or some unresolved question from previous lessons. On day 1 of my observation, this was about the ethics and morality of supporting the life of a hydrocephalic child. In the weekend news, parents of a two-year-old hydrocephalic child were appealing for funds to the tune of US$5 000 to send their child for treatment in a neighbouring country. Sipho and her students got so engaged in this discussion they seemed to enjoy it very much. It went on for close to twenty-five minutes, and I was immediately amazed by Sipho's flexibility with time during that 70-minute lesson.

On getting to the topic of the day (Day 1), Sipho says something like this:

We looked at the structure of the kidney last week. We saw that.......(she gives a descriptive rundown). Today we are going to look at ultrafiltration in the Bowman's capsule and re-absorption in the proximal convoluted tubule. Does anyone have a question before we move on? (No question). If there are no questions we will move on. Will the group which is presenting on ultrafiltration please come over and present what you have for us.

One boy then moves to the chalkboard to put up some headings and drawings. After defining 'ultrafiltration' he goes on to describe the whole process, constantly referring to his notes. He struggles sometimes to express himself clearly, or to give a coherent explanation, and when this happens, he throws a glance at Sipho, perhaps to gauge her reaction. The class sits quietly for some time until he asks for questions. One student says he did not understand the role of the basal membrane in the kidney nephron. Then, interchanges occur for a while, which are student-initiated and directed not just at the presenter but at the whole class. The involvement of the presenter's colleagues in the group is not very apparent, and most of this time Sipho sits quietly in the front desk watching and listening.

After a while, when the presenter seems stuck and unable to explain some of the class's questions, Sipho joins in and explains what the presenter should have done, how he should have explained and the type of information he should have searched for. She gives her answer to an unresolved question (on the role of active transport in the proximal tubule), and later calls for further questions or challenges to the information given in the presentation. The bell rings and it is time to move to another lesson. Sipho quickly tells the other groups that are to present next to get better prepared through reading to answer their colleagues' questions.

The events described above indicate that Sipho probably wants her students to take control of the topics of study in the syllabus, to organize their information, and to share their understanding of content. She gives out topics for presentation ahead of time, and takes a back seat during students' presentations, ways of encouraging autonomy and initiative. She is certainly promoting dialogue among students, and although she may seem to have had less interactive dialogue herself with the class; she availed herself at the beginning and at the end of the class activity.

The study of the kidney is of relevance to biologists and people in general since it relates to health and eating habits including food and fluid intake. The media, traditional and social, carry reports on renal disease and kidney dialysis, the sale of kidneys in some countries, etc. I did not observe Sipho recap on such or other social issues to place the scholarly study of the kidney into the students' context, even if it meant creating such context for them; e.g., the students who had never heard of kidney donation would suddenly think about themselves, perhaps on the lines of how they would respond to an offer to donate or sell a kidney.

On day 2, almost the same procedure occurs; one other 'group' presents on selective re-absorption in much the same fashion as before. After this lesson, I had an informal talk with Sipho about her class and teaching, and
we shared bits of our education and teaching backgrounds. She mentioned the gender imbalance in hers and other science classes generally. She also talked briefly about her career aspirations. I was able also to suggest to Sipho to try a few changes to the group presentations, for instance, having two or three presenters sharing the floor as a panel or one after the other. This was my way of contributing to the success of the class, and to help Sipho live out her wish to maximize student participation. I could have also suggested to Sipho that she change her seating position during the students’ presentations to mingle with the class more freely so as to extend trust and confidence on her students. Students traditionally accustomed to the teacher providing ultimate answers and solutions will, even in an empowering environment, still look to their teacher for verification and authentication of their knowledge constructions.

Day 3 was a practical lesson, and on Days 4 and 5 I observed some evidence of Sipho incorporating ideas from our discussion, such as eliciting students’ knowledge at the start of a lesson. For example, Sipho would put two words on the chalkboard (e.g. urea, glomerulus) and ask students to discuss the connection in pairs and then report to the class what they had just discussed. Also, Sipho began frequently to use the words, "Could you please explain yourself more clearly so that everyone understands."

3.4. Expressions of Critical Reflection and Critical Self-reflection

I initially interviewed six students individually from this class before inviting another five to a focus group discussion. I had selected them on the basis of their responses to the questionnaire, their participation in class, and their gender. I was interested in following up some of the students’ responses to the questionnaire which were typical or atypical of the class’s responses. I also wanted to understand how the active and the passive participants felt about the class’s student negotiation environment. I highlight a few individual responses and summarise the common ones below.

Most of the students rated biology highly (first and second) among the three A level subjects they were studying, and they considered the subject generally relevant to their lives and career aspirations. One said:

I think the subject (Biology) is good. I am actually studying things that I can use outside class, things that relate to my body and the plants and animals around me. I can explain a bit about how the body functions. But I find Mathematics and Physics more challenging because of the calculations and interesting problems involved, even though I will not use much of the knowledge outside class.

This student (who was almost always very active in class) was probably fascinated by the cognitive activities of manipulating highly abstract and objective knowledge such as the solution of equations, the application of rules, formulae, and algorithms. He, however, appreciated the personal meaning that some biology topics bring to his daily life. In line with his other interviewed colleagues, this student felt that student negotiation often featured in class as well as outside class, and it was based mainly on what they would have read in their textbooks. Probed on item 27 of the CLES which proposes that, In this class students explain their ideas to other students, the above student alluded to the fact that often students handed down their ideas rather than explain them, until the end when discussion heated up. One girl, who was almost always quiet during the lessons I observed, had this to say:

We read a chapter or a passage on what the teacher will have told us to read about. My friend will maybe read a different book from mine. If we have time in the evening, we meet and discuss what the topic is about. She may have understood one way and I will have understood the other way. Then we argue about who is right and which book is right........ In class, other people tend to continue arguing, and I usually don’t follow their arguments.

I asked her if she thought that not being involved in a class discussion meant that she was not concentrating on what was going on. She replied:

I do try to concentrate, but it’s like some people like to talk more than others and they make you feel you know less.

It is here perhaps that Sipho could incorporate smaller group discussions, or ensure equitable load sharing between and within groups. It is often impossible to engage every learner equally but delegation of tasks within a voluntary setting achieves inclusiveness.

On what influenced her teaching style and methodology without a professional teacher qualification, and suggesting to her that perhaps it was the way she herself had been taught, she had this to say:

When we were taught, we were taught. We were told that this was that, and that’s it..... But I realized as I learnt myself, that I would learn more if somebody would allow me to do the talking for a change. So in most cases I will give the platform to the learners themselves, in the form of job cards, and.... that way I realized that they participate more, and they learn more.

On how the students acquired or derived the knowledge they displayed by participating in class discussions, Sipho said she encouraged them to source information from textbooks and other sources, and she was there to correct and "edit" their views, encouraging them to be as independent as possible. She encourages them to challenge her information, she claimed. Letting students lead discussions featured very prominently in her lessons because, she says:

I realized that standing in front of them (myself),... is not as effective as giving them parts of their syllabus to go and do for themselves. I applauded her for bringing in external relevant issues for class discussion and I encouraged to her to find such topics that would link directly to her topics. When I suggested to her to be more actively involved in such student-dominated presentations by making available learning support materials such as diagrams, audio-visual aids and resource persons, she alluded to the fact that she often did not use those because of practical constraints and the rigidity of ready-made materials. Moreover, the need to cover the syllabus reduced the time for preparing learning resources and integrating them into most lessons.
3.5. Reflection on Beliefs, Practices and Destinies

Sipho reflected strongly about how to make her teaching personally relevant to her students’ lives, and thus her routine of including snippets from daily life as a regular feature in her lessons. She accepts that scientific knowledge should be treated as uncertain, but finds it difficult to totally allow students to be critical of her and of accepted scientific knowledge because she and her students are working towards an examination, which, she thinks, does not allow unlimited room for critical analysis and divergence of thought. She believes that drawing from the cultural background of her class, the socio-cultural contexts of knowledge construction and management do not allow for open classes. This is so, given that the social reality of traditional classrooms is governed by powerful cultural myths that restrain the discursive practices of teachers and students, a dilemma only ably addressed by critical constructivism [18].

With some foresight, Sipho was clearly linking her teaching with her own life, her future and her ideological outlook. She had feelings about teaching and targets for improvement, saying she would have liked to see improvements in her students’ pass rates, as well as a confirmation that her teaching made a lasting contribution to their life after school. Deep critical reflection would further link her to reflect further about other dilemmas in science teaching and learning, the perceived backwardness of indigenous culture, the negative effects of colonisation, the horror of subjugation and foreign domination, and the thought of whether pure African traditionalism will ever triumph. [19] note that in the modern crisis-ridden world, we are forced to reflect on the world, how we live in it, our actions and our roles and responsibilities towards one another and the environment. In the advancing technological world, we are challenged to produce scientists and engineers who reflect critically and contemplate deeply on how we apply our scientific and technological knowledge in pursuit of social and economic development. And in this study, the learnings from critical reflection on personal relevance of subject matter and student negotiation should promote transferrable learning to address short and long term life goals including debates and challenges of public health, social welfare, cultural heritage, inter-cultural pressures and friction, and destinies of future generations. Of necessity, students need to engage in metacognition, which is especially important to move students out of passivity to activity where they are aware of and monitoring their own understanding during the learning process so as to evoke transferrable learning [20].

4. Conclusion

Teachers of science can cultivate a culture of self-evaluation and self-appraisal in themselves and in their students consistently throughout their classroom encounters. It is hoped that this culture, coupled with active engagement in social and economic development initiatives, sets a conducive environment for irreversible and sustainable personal development [22], an ingredient for sustainable national development. The requisite for sustainable development hinges on relevant knowledge processing for developing countries which involves integrating existing cultural and community-specific knowledge with other knowledge accruing through the experiences of a people. The erstwhile motivation for wholesale acquisition of western knowledge is no longer encouraged [23]. The situation described in this paper indicates hope to those who give thought to their students’ goals and capabilities while in class, and gives room for improvement on the practices described.

On the broader global scale, the development of African communities who still cling faithfully to traditional beliefs and practices depends on them joining the crusade for change, crossing borders into the science culture, but not necessarily to western culture. Cultures will never remain stagnant for any length of time. It is the magnitude and direction of change that has distinguished one nation’s historical path from another. Whatever the speed and zeal with which developing Africa accommodates change and adopts new methods and technologies, it is worth considering that the learner and the citizen in the industrialised country remains ahead in many ways. Western science, a tool so far affording privileges to a section of the world, yet available to all, may well be the solution to cultural uncertainty through building strong foundations of knowledge that can bridge nations, enlarge fundamental freedoms, and promote peace and democracy.

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Statement of Competing Interests

The authors have no competing interests

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