The Effectiveness of Portfolios as Chemistry Teaching and Learning Tools

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Abstract

A science student portfolio was used to replace an O'Level chemistry textbook in the teaching and learning of O'Level chemistry in a high-density suburb of Gweru, Midlands Province, Zimbabwe. Data were collected from the portfolio, observations and interviews. Students initially perceived the researcher as tough, strict and unkind; and chemistry was perceived as difficult, involving lots of mathematics, confusing experiments and reactions, which were difficult to comprehend. Students' negative perceptions, however, vanished as students realized that the portfolios provided appropriate platforms for motivation, opportunity for self-directed learning and self-reflection, responsibility for students' own learning, goal-setting, and opportunity for research.

Key words: Portfolio, observations, interviews, instructional tool, constructivism, stake holders, perceptions, conceptions, misconceptions, tests.

Teachers' teaching methods/styles are of great influence on students' views and attitudes towards science because teachers are the main instrument for initiating students into formal education (Shumba, 1995). A teacher's philosophical orientation, his/her understanding and knowledge of the nature of science, determine his/her view and shape his/her attitude, approaches, and method of teaching (Madzinga, 1992). This in turn influences students' conceptions and attitudes towards science. Poor initiation to science invariably leads to students' flight from science classes (Shumba, 1995).

Traditional science curricula are continuously being modified from to make learning more effective and to meet students' learning needs (Cain, 2000). The current emphasis is towards hands-on, minds-on science, characterized by authentic methods of assessment, such as self-assessment, portfolio and democratic assessments, which assess all components of modern and comprehensive science education programs. This type of program measures skills, processes, and attitudes (treating science as a doing, rather than learning or studying science). Teachers should, therefore, involve students in learning the content, and at the same time, engage in its processes. Students are expected to think critically, to investigate science concepts or problems, to have positive attitudes towards science, to self-reflect and to own the learning process. The vast amount of scientific knowledge that is constantly changing and growing does not allow students to memorize the large quantities of discrete facts. Teaching strategies that promote understanding of concepts and construction of meaning by combining prior knowledge with new information, such that the new knowledge provides personal meaning to the student, are being pursued. Educators now seek to provide appropriate learning experiences to help students develop their mental capacity (Cain, 2000). Teachers are now expected to desist from attempting to transmit information as if students are *tabula rasas* or sponges that absorb information. For abstract subjects, such as chemistry, teachers need to relate abstract or non-visual concepts and processes to concrete experiences of students. Things like atoms are too small to be seen, electron movements and transfers appear just like a world of imagination, and reactions may be a manifestation of what is beyond students' imagination. Hence science educators must come up with appropriate teaching approaches that enhance construction of meaning by students (Licata, 1992). There is need to think of approaches that allow students to construct meaning, such as inquiry-based science programs rich in experiences relevant to the learners (Cain, 2000).

Traditional test exercise-books and notebooks do not give students the time to self-reflect and diagnose strengths and weaknesses or effectively give time to stakeholders, such as, parents and guardians to contribute to children's education. Public attention involving children's achievement and performance in schools increased during the later 1980s and the early 1990s (Catty, 1992). A general consensus for assessment reform is reflected in the volume and variety of professional literature on various assessment methods, and authorities seeking alternative means to evaluate students.

There is an attempt to shift from a dependent mode of education which characterizes many students' experiences at high school, and even to some at university level, to an independent mode. Pheeney (1998) defines portfolio as a collection of student's work, teacher's observation, parental and peer comments, as well as any information gathered as a result of other assessment strategies. It may also be defined as an edited collection of evidence of growth and reflection representing progress towards personal goals (Moseley, 2000). The entries are selected and commended on by the student, the teacher, the guardian, and peers. Thus portfolios are records of students' processes of learning, containing what the student has learnt, and how the student interacts with others (Giroux, 2000). Portfolios also invite revisiting of concepts through different learning modalities, encouraging interdependence and responsibility of all students in a group setting, allowing students to use fully their creative energies and potentials and improve critical thinking and evaluation. This collection of students' work demonstrates learning over time and shows how the students have progressed in learning science content, skills, or processes (Cain, 2000).

Portfolios' most desired outcome is to have students assume learning responsibility and develop a desire to do their work best, facilitate increased involvement in the assessment process, and give students greater responsibility for their own learning (Lumina, 2005). The ability to think about what one does and why, to assess and reflect one's past actions, current situations and intended outcomes, is vital to intelligent reflective practice (Moseley, 2000). Thus, in the learning process, students pause to think about their work and make sense of it. Their reflective process influences how they grow academically by influencing how successfully they are able to learn from their experiences (Richert, 1990).

Portfolios come in many shapes and forms (Pheeney, 1998). The shape and form of a portfolio chosen is determined by the purposes of the portfolio and the resources available. Three types of portfolio are indicated: (1) the working portfolio, (2) showcase portfolio, and (3) evaluative portfolio. The working portfolio contains most or all of a student's work in progress. Typically the working portfolio is not directly evaluated but can be used for assessing future instructional strategies and reviewing a student's progress over time. The showcase portfolio predominantly contains end products such as term papers, finished projects, and samples of best efforts. The selection of these end products can be determined exclusively by the teacher, but most often involves student input. This portfolio type may or may not be used for evaluative purposes. The evaluative portfolio contains records needed by the teacher to evaluate a student and contains more than just a student's best work.

All comprehensive portfolios showcase a student's abilities and skills and a teacher is able to monitor a student's growth. Thus, the portfolio provides an opportunity for the teacher to have an input on the student's progress as opposed to simply assessing the strength and deficiencies of a final product. According to Pheeney (1998), the portfolio can also foster student self-reflection and organizational skills if they are involved in ongoing review and selection of their portfolio inclusions. This process helps students to recognize their strengths and weaknesses and, consequently, to identify areas for potential growth. Most students develop a strong sense of responsibility for their own success and feel empowered when they are asked to convert their working portfolio into showcase portfolio, because they are being asked to select their best or favorite pieces of work. This motivates them to create better end products. Thus, the portfolio can be used for motivating, providing feedback, and diagnosing strengths and weaknesses and establishing level of achievement (Lumina 2005).

The portfolio, as an approach to teaching, clearly aligns itself to the new vision of science teaching that emphasizes facilitation of student's ownership and control over their learning as advocated in inquiry-based learning (Cook & Taylor, 1994), where teachers are blamed for being reluctant to move away from teacher-centered approaches. By encouraging individual responsibility to one's learning, the portfolio supports the constructivist approach to teaching and learning models. The approach calls for learning that is hands–on, minds-on (Haury & Rillero, 1994). This entails that students are actually allowed to perform science as they construct meaning and acquire understanding. It enables students to participate fully in a learning community where the teacher is not the only source or owner of knowledge and information, but a team leader and facilitator. Pheeney (1998) suggests that such profound changes in the way students are taught would result in science educators separating the goals of teaching, from those of learning more clearly, and the curriculum material would be designed more effectively. This would also help teachers realize that rote learning and repeated practices are not likely to generate real understanding and useful knowledge. Yager (1991) suggests that the new emphasis by science educators should encourage educators to build-in adequate time for reflection and analysis, resulting in students using all ideas they generate, thereby facilitating meaningful learning. By encouraging self-analysis, the portfolio becomes a suitable instrument to achieve learning and teaching in line with the new vision of teaching that calls for students to collect real evidence to support ideas, and reformulate ideas in light of new experiences and new evidence.

The use of portfolio supports the constructivist learning model as suggested by Beneze & Hudson (1991) who proposed that students should be actively involved in constructing meaning of their world. Effective learning occurs most when learners are encouraged individually, and in groups, to explore phenomena in their natural and social environments. They further argue that effective learning occurs most when learners are encouraged to formulate questions for enquiry, to seek answers through observations, experiments, research and consultation with those more knowledgeable than themselves. Teaching and learning becomes more meaningful when learners are encouraged to present, explain and justify conclusions and to evaluate both the process and the outcome of their inquiries through discussions with their peers and teachers.

The constructivist theory states that learners' role should be an active role, not a passive one. Since learners base their understanding on their prior knowledge, learners construct meaning from the experiences they encounter during classroom activities and their everyday life, the most important factor influencing meaningful learning being what the learner already knows (Ausubel, 1963; Ausubel, Novak, & Hanesian, 1978; Bordner, 1986; Novak, 2000). Since the portfolio is a document in which the students reflect what they know before and after every topic, the science educator may make use of it to elicit students' conceptions and misconceptions and then help the students to construct new conceptual frameworks from the existing ones by assisting them to fit or integrate new concepts into the pre-existing conceptual frameworks or discard misconceptions for correct ones. The Constructivist Learning Models (CLM), thus, appear to take into account the cultural and religious backgrounds students may bring into the science classroom (enacted scientific worldviews). The scientific worldview is the way some one views nature and science in relation to his/her cultural beliefs, norms, and values. The enacted worldviews become the basis for acquiring new knowledge (Ausubel, 1963; Ausubel et al., 1978; Novak, 2000; Cobern & Loving, 2000). The portfolio becomes instrumental because it is a record of students' prior knowledge and past experiences as influenced by their cultural beliefs, norms, and values. The role of the teacher, therefore, is that of the negotiator for cultural border-crossing by helping students move from their enacted worldviews into the culture of school chemistry and back into enacted worldviews (Aikenhead & Jegede, 1999). While research clearly reveals advantages of instructional strategies based on constructivist model of teaching and learning over models based on behaviorist theory and rote learning, practice remains rooted in behaviorist models (Beneze & Hudson, 1991).

A preferred model of instruction should be based on strategies that emphasize engaged learning in which students create meaning from their own experiences in order to develop skills and knowledge needed to construct their own understanding of science & technology and the world in which they live (Haury & Rillero, 1994). Thus, according to Haury and Rillero, the thrust should be towards hands-on minds-on learning. Garcia (1991) proposes that teachers should significantly change the strategies they have used traditionally and realize that studying content of chemistry is not the same as doing chemistry. They should move from their traditional roles as knowledge deliverers, disseminators, and accept a new responsibility as facilitators, coaches, and coordinators. Hurd (1995) proposes that science educators should shift from dependence on textbooks to using them simply as references to support hands-on minds-on learning. Courtney (2000) pointed out that teachers will discover a need for new assessment methods as they make the transition to inquiry centered science. Students benefit from inquiry-based science instruction because it is interest driven. Instead of reading a textbook unit and doing an activity that "proves" the textbook as correct, students discover concepts and relationships through their own questions that are reinforced by textbook resources (Barrow, 2000). The new vision of teaching and learning (NVTL), as opposed to traditional science learning, takes into account current thinking in the history and philosophy of science learning (Shumba, 1993). The NVTL defies the standard philosophy of science which consists of scientific research by scientists, textbooks as compilation of truths, and teachers as transmitters of cumulated truths to the next generation (Loving, 1991). The teachers feel comfortable with the traditional didactic, authoritarian approaches which empower them, hence they do not favor models that give students flexibility and empower students to participate in decision-making (Stage, 1993). A true portfolio must be student-owned, with content that reflects what the student knows, cares about, and provides an opportunity and structure for students to document and describe academic knowledge & reflect on what, how, and why they learn (Moseley, 2000).When students become partners in the learning process, they gain sense of themselves as readers, writers, researchers, and thinkers. As they reflect on the different aspects of their learning, they develop tools to become more effective learners (Mifflin, 1997). Once students have reflected on their learning, they are ready to set new goals for themselves. They should be encouraged to reflect on their learning journey at regular intervals as they work towards these goals. Teachers encourage students to record their reflections during teaching/learning to help them reaffirm goals and motivate them to move towards meeting each one of their goals.

With practice, students who self-assess become more conscious learners able to apply knowledge of their learning needs and styles to new areas of study. As they become more active participants in the evaluation process, they will begin to evaluate their strengths and attitudes, analyze their progress in a particular area, and set goals for future learning. Student's observations and reflections can also provide valuable feedback for refining the teacher's instructional plan (Mifflin, 1997).

Teachers can best support their students' in their efforts for self-assessment and evaluation by providing regular opportunity for students to reflect on their learning process. They may guide them with reflection questions such as "What did I learn in this chapter? What did I do well? What am I confused about? What do I need help with? What do I want to know more about? What am I going to work on next?

Most teachers who have employed the portfolio have indicated that portfolios have an impact on their teaching strategies and are effective as means to communicate with their students. They say that documentation of students' progress fully was a major benefit. Weaknesses of the portfolio were indicated as lack of understanding of the portfolio on the part of the parents and the fact that they are time-consuming (Fredrick & Edward, 1996).

The portfolio has given students opportunity to demonstrate conceptual understanding, creative improvement, as well as revision and collaboration, and students were able to apply their findings, and conclusions to new or even unfamiliar situations, and the evaluator was able to consider the students' entire thinking process (Mahood, 1994). The portfolio has been used at many levels, including on university students, and was reported to facilitate self-directed learning. It helped students assume greater responsibility for their own learning, forming a framework for motivation, feedback, diagnoses of strengths and weaknesses, and established the level of achievement at the end of the course (Lumina, 2005). Students used the portfolio to reflect, check on progress and identify strengths and weaknesses. The classes were observed to increase in numbers as the students enjoyed the learning process (Jeffrey, 2001). The school under study has witnessed flight of students from chemistry to less demanding subjects such as biology and human biology. The portfolio might influence the students to continue with chemistry.

Despite all the desires for portfolio use, the place for the portfolio in science education in general, worldwide, remains to be determined (Collins, 1992). However, there appears to be no formal research on science student portfolios in Zimbabwe (Kamen, 1996).

Research Questions

1. What are the effects of integrating the science student portfolios on effective teaching and learning of O'Level chemistry?
2. What preconceptions do students have about chemistry before they are introduced to the subject?
3. How will students, parents and the administration respond to the introduction of science student portfolio as a new instructional and assessment tool?
4. What problems will teachers and students encounter in the process of implementing the science student portfolio?

5. Will the portfolio have effect on the flight of students from chemistry classes?

Methodology

The research paradigm used in this study is a constructivist perspective which assumes that knowledge is not acquired passively (Yager, 1991). Constructivist teachers of science promote group learning where two or three students discuss approaches to a given problem with little or no interference from the teacher. There are many paradigms in the field of educational research, with some approaches being more useful than others (Magagula, 2004).

The qualitative methodology is a useful strategy for understanding how students learn using the constructivist perspective as it draws from the theoretical framework of phenomenology, which assumes that multiple realities are socially constructed through individual and collective definition of the situation (Macmillan & Schumacher, 1993). Since the qualitative researcher is, thus, part of what is being studied (Priscilla, 2002), the researcher will have direct understanding of the circumstances of the object of study because he/she will be in the latter's shoes. The researcher and the other participants are active partners in data collection and the participants respond to semi-structured, open-ended and other questions spontaneously and naturally. Thus, the researcher gets close to the respondents, situations and phenomena under study. The researcher's personal experience and insight are an important part of inquiry and therefore critical in understanding the phenomena, data analysis and interpretation being from the emic point of view.

This research was designed to be a case study to permit an intensive, holistic description and analysis of the implementation of an innovative teaching strategy in a particular science class at one of the high schools in Zimbabwe. A case study is a flexible and adaptable, in-depth study of instances of a phenomenon in its natural context and from participants involved in the phenomenon, which allows for prolonged engagement with participants (Bogdan & Biklen, 1992; Macmillan & Schumacher, 1993; Borg & Gall, 1996). The use of multiple methods of data collection about a phenomenon enhances validity of findings through triangulation (Borg & Gall, 1996; White, 2000) and the findings of a case study could be transferable to other situations which are similar, depending on the judgment of the reader (Lincoln & Guba, 1985).

This study employed action research by teaching one of the two O'Level chemistry classes using student portfolios and the other employing standard practices. The researcher guided students construct portfolios which they used to record the events that took place during the teaching and learning process. They did this by recording topic reflection and test reflection, projects, summary of assessment and portfolio conclusions. By creating a column for parents and guardians in the portfolios, parents and guardians were actively encouraged to scrutinize how their children were being taught and how they were learning as they were allowed to make comments in the portfolios. The headmaster of the school and the class teacher were invited to comment on the activities of the participants. The researcher used the information from the portfolios to fine-tune his teaching approach.

Delimitation of the Study and Sampling

The study was carried out at a school in Gweru, Midlands Province, Zimbabwe, involving a form 3 physical science class, consisting of 40 students (14 girls and 26 boys). Data collection took place between January and April of 2008. The school had two form 3 classes of forty students each, doing chemistry and other subjects. Form 3 was chosen because the students had just completed the Zimbabwe Junior Certificate studies, had not yet been introduced to chemistry as a subject, and had not yet used portfolios.

The students were told to write their background information on their science portfolios which included where they stayed, where they did primary education, and what their grade seven results were. The information was checked against school records for accuracy. The grade seven results for both classes ranged 5-9 units. The students had been placed into the two classes randomly hence the two classes were practically equally talented. Just one of the two classes was chosen for the portfolio because it is usually impossible to study a larger sample due to time and financial constraints. According to Pheeney (1998), portfolios can become massive unmanageable, unfocused and cluttered, as a result, they often get abandoned by the teachers and students. For large classes, some teachers end up having endless supplies of checklists, scoring rubrics and reflection sheets never to be seen or heard of again.

A member from each of the two classes was called up to pick up a card from a pile of ten cards. Five of the cards were labeled PI (for Portfolio Instruction) and the other five were labeled SI (for Standard Instruction). The cards had been randomly mixed by shuffling. A student from form 3E picked up a card labeled PI and form 3E became the subject of this research study. A student from form 3D picked up a card labeled SI and form 3D was taught following the standard method. However, the researcher was the chemistry teacher for both classes. He paid similar attention to both classes and compared the students' performance on a fortnightly basis for the duration of the project, effectively using class 3D as a control, only as far as results of fortnightly tests were concerned.

Research Instruments

The researcher was the chief instrument for data collection. He was the participant observer as he observed students interact with the portfolios as teaching, learning and assessment tools. Open-ended interviews were used to collect information about students' backgrounds, preconceptions, perceptions, attitudes and reactions to portfolios such as whether or not they were gaining from portfolio use. The interview is a two-person conversation initiated by the interviewer for the specific purpose of obtaining research-relevant information, and focused by him/her on content specified by research objectives of a systematic description, prediction and explanation (Kerlinger, 1970). The interview may be used as the principal means of gathering information having direct bearing on the research objectives. This research employed the unstructured or open-ended interview which, according to Kerlinger (1970), offers an open situation having greater flexibility and freedom. After the interview gains rapport, certain types of confidential information that an individual might be reluctant to put in writing may be obtained.

Gaining Field Entry

The researcher got an introductory letter from the University of Zimbabwe which assured the headmaster that all the information was to be held in strict confidence. Permission was also sought from the Provincial Education Director, Midlands Province, Zimbabwe, as suggested by Best and Kahn (1993). The consent of students and their parents or guardians was sought immediately after the headmaster had given the go ahead.

Being accepted by students was made easier after the headmaster had introduced the researcher as their new chemistry teacher at the beginning of the year. The researcher, however, expended considerable effort in introducing the new approach to teaching and learning chemistry. Students initially did not understand why the test exercise book was being replaced by the science student portfolio. Initially students feared that it was going to be more expensive until they were convinced that it was cheaper than the test exercise books. Within two weeks of starting, students had grown a liking for the procedures and were soon proud to own a portfolio, which they were seen to walk possessively with during break times.

The administration became very supportive of this new approach after the researcher explained the intricacies to them. Support of the parents and guardians was secured through the assistance of the headmaster who communicated with them in collaborated with students.

Data analysis

Data analysis was an on-going process, involving reflecting on notes from observations, interviews, and student portfolios, various themes emerging as the research progressed (Macmillan & Schumacher, 1993). Each student portfolio introduction indicated areas of residence and ages of students. Forms 3D and 3E consisted of students of almost the same age (15-17 years) who resided in the same high density suburb, and having done their pre-school and primary school education in the catchment area of the school, graduating from primary education level with results ranging from 5-9 units.

Analysis of the portfolios revealed that students perceived chemistry as a hard subject (50%); a subject which can never be passed (40%); the hardest subject (50%); not a cheap subject (100%); a subject which can never be understood (10%); a hard nut to crack (30%). Chemistry teachers are unkind or cruel (50%), and always say chemistry is tough (70%). Chemistry is a demanding subject which needs reading and demands a lot, requiring concentration and understanding (100%); full of experiments which confuse (70%); requiring hard work and lots of mathematics (60%). Chemistry is a frightening subject from which pupils drop (70%); I was frightened and nervous when we started to do chemistry (80%); comments by other students frightened me (60%); I was about to lose hope (30%).

Thus chemistry is portrayed as a hard, demanding, frightening subject and the teachers who teach chemistry are negatively perceived by students. The teachers also induce fear in students by saying negative things about the subject. Hence the students are observed to carry negative ideas into the classroom. This influences the learning process and probably has an effect on the flight of students from science classes as pointed out by Shumba (1995). In this case study the researcher attempted to improve educational practice by coming up with teaching approaches that motivate and create greater responsibility for students own learning (Lumina, 2005; Nyoni, 2007).

Results and Discussion

Teaching approaches preferred by students

Analysis of sections of the students' portfolios which revealed information about how students preferred to learn chemistry convinced the researcher that the project would let students feel empowered and own their learning process, as suggested by Pheeney (1998). The preferences were indicated as follows: Display (2%); Experiments (30%); Discussions (12%); Theory (2%); Visits to related companies (16%); Group work (16%); Demonstrations (20%); Projects (2%).

Thus the majority of students preferred learning through experiments, demonstrations, group activities and visits to related companies. This might be reflective of the way they were taught during their grade seven and ZJC courses.

Student' beliefs, attitudes and motivation

Despite the negative perceptions they held, some students echoed positive statements in their introductions, as the following excerpts demonstrate.

I will not drop chemistry because it is important in my life.
I want to become a medical doctor.
I am willing to put more effort in to chemistry learning.
I want to be like James Chadwick or Dr Brown of the Brownian movement.
I think I am going to get an A in chemistry.
When it is tough I will pull up my socks.
I will read hard. As long as one concentrates, there is no hard subject.
I can prove that chemistry is easy.
I can come up with flying colors, so I want to work extra hard.
For one to live like a king, one needs to work like a slave.
I want to proceed with chemistry, stay focused, and pass.
I want to achieve many things in chemistry through experiments and demonstrations.
I enjoy chemistry.

The researcher took advantage of the self-drive by the students to initiate them into the world of formal chemistry education, using the portfolio as the main motivational booster in this research.

Opportunity for self-directed learning

One of the aims of introducing portfolios was to promote self-directed learning which also promotes motivation and ultimately facilitates learning (Lumina, 2005).This is reflected in students' topic reflections when students suggest ways of dealing with identified problems in the topics they learnt and tests. One of the students, Lindiwe said, "I did not understand the statement that says the relative atomic mass (A_r) is the mass of an element compared to $^1/_{12}$ of the carbon 12 isotope. I think I have to find more detail about A_r and M_r so that I can understand more. Another student, Trevor said, "I learnt to do assignments with members of my group and it improved my attitude towards learning I was as busy as a bee all the time looking for information. Another student, Tom, showed lack of understanding of electron sharing in CO_2 and NH_3 covalent bonding and transferring of electrons in forming $MgCl_2$. The student said: "I am determined to find more information in the library and I need to practice with more elements".

Opportunity for self-reflection

Tafadzwa wrote "Learning through reflections, projects, and tests made me improve. I now have a scientific mind towards everything done at home. I used to cook 'sadza' without knowing that I was performing chemical reactions. My mind has revolved towards chemistry. I see chemistry all around me."

Sharon wrote: "I also discovered that I need to boost my confidence because I used to panic every time before writing a test in chemistry." Jojo wrote: "I am ashamed of my graph. My marks are now low. I shall try and improve my graph through revision."

The above statements vindicate suggestions by Lumina (2005) that portfolio can assist students reflect on their learning in a manner that can enhance their learning; and Moseley (2000) who pointed out that the ability to think about what one does and why, while assessing and reflecting one's past actions, current situations, and intended outcomes, is vital to intelligent practice that is more reflective than routine.

Further support is given by Mifflin (1997) who wrote that students need to examine their work and think about what they do well and in which areas they still need help. This was also implied by Pfidzai who wrote: "I am still confused about electronic configuration but I am already getting help from the teacher and my classmates."

Responsibility for own-learning

The portfolio is useful in helping students develop and assume a sense of responsibility for their own success and feel empowered for their own learning (Pheeney, 1998). By suggesting solutions to their identified problems, students are taking responsibility for their own learning. For example, June blamed himself for not revising seriously. Thembisa concluded: "Now my mind is made up. I shall work with whatever I have to pass chemistry."

The sentiments by the students are compatible with Moseley's statement that a true portfolio must be student owned , with the actual content reflecting what each student knows, cares about, and is able to do and not able to do.

Goal setting

As students reflect on what they have learnt, and how they learn, they develop tools to become more effective learners. Once students have reflected on their learning, they are ready to set new goals for themselves (Mifflin, 1997). This was revealed in the students' tests and topic reflections. After a self-reflection exercise, Vimbiso said, "I am now working on the next topic, chemical bonding." After his test reflection, Gillion said: "I want to study extra hard so that I achieve better marks and high scores in the next test." Mobbie said: "I wish to achieve 'A' grades in the upcoming tests. I know I will meet my targets. I will continue reading and researching from my elders and the library so as to beat my target of 75%".

Opportunity for research

The use of student portfolios gave students an opportunity to do research. An analysis of students' test and topic reflections indicated that students aim at improving by visiting the library for research. Students also did group and individual research on any chemistry topic of interest and an industry, including ZimAlloys, Chibuku Breweries, ZISCO Steel, Bata Shoe Company, and ZimCast. The industries are not directly stated in the syllabus, but students got some important chemistry issues from these researches. Issues such as pollution, fermentation, diseases, and greenhouse effect were encountered.

Students reported on summaries of their research work to demonstrate their understanding. Some of the research results were presented to the class. For example, Tenboy presented his findings on Death Chemistry, in which he reported on the use of chemical weapons on Lebanon, by Israel, and outlined the harmful effects of the chemical elements encountered in bombs. He also reported on the advantages and disadvantages of studying some of the aspects of chemistry and concluded: "The study of some of the areas of chemistry should be restricted to safe minds and hands, since the study of chemistry by irresponsible people may lead to death of people and destruction of property. Look at what happened in Hiroshima and Nagasaki at the end of World War II and the illegal experiments on human beings by doctor M^c^Gowan of Mnene Hospital in Zimbabwe." Zvaitwa presented a summary of his findings on occurrence, properties, & uses of silicon, revealing that the student had gained an understanding of the chemistry of that element.

The role of stakeholders

The students, in their introduction, indicated the methods through which they preferred to learn chemistry. By providing a section in the portfolio where parents and guardians could make comments on their children's learning process, the researcher incorporated them as important players in curriculum implementation. The administration, in the form of the Deputy Headmaster and the Head of Department, played their role by supervising the portfolio project. The parents made their contributions to the teaching and learning process by making constructive comments. For example, Charity's mother said: "Allow me to extend my sincere appreciation to you for the best and prudent ingenious method for teaching chemistry. My little girl has become the focal point in the house because of the project. We thought it was a mere statement until we saw the progress. Charity has developed positive attitudes towards this subject. To her it is like chemistry is the only subject in the curriculum. The process impact, significance and cause of individual activities, chemicals and sequences are her everyday talk. We hope that this will continue making a significant impact in her life and her quest for knowledge and understanding of the subject.

Charity's mother was also guardian to her niece Pepe in form 3D. About Pepe, she wrote: "My niece, Pepe, feels she is unlucky to be in 3D. She has followed the progress of Charity with envy. She would like to be considered for transfer to form 3E at the earliest opportunity. She is, however, practicing with Charity at home, with benefit."

Chipo's parents commended: "Your portfolio is encouraging. Make sure that you remain focused. Pride's brother commended: "His performance on typical questions has improved. He now demonstrates a scientific mind at home. The portfolio enhances the urge to research. "Zvai's parents wrote: "She is doing well in the tests but we will encourage her to work extra hard so that she improves on her score."

Supervisory comments by the school Headmaster, Deputy Headmaster and the Head of Department encouraged the researcher and influenced his teaching process. The Deputy Headmaster suggested: "Before commenting on the new topic, pupils should be encouraged to indicate how they managed to clear grey areas from the previous topic. They should also give examples of new concepts that came up in the topic, link the knowledge to real life day-to-day activities, and suggest how life can be improved by application of new concepts. The Head of Department wrote: "The most important aspect of this project is in providing a learning platform where there is feedback/interaction among stakeholders, i.e., teachers, learners, parents, and guardians.

The Headmaster acknowledged: "This approach is the first of its kind in the school and it will go a long way towards the production of high quality results in chemistry at the school.

It motivates students to learn for a purpose. They are being attracted to the subject rather than being frightened as what has been happening before the advent of the portfolio. It would appear that the involvement of all stakeholders in the implementation of the curriculum may improve the teaching and learning of chemistry in schools.

Have the students changed their perceptions & attitudes towards chemistry?

Each student was required to write a closing chapter in his/her portfolio in the form of a conclusion at the end of the term, reflecting on experiences of the term. They were expected to write on difficulties, learning moments, and gains encountered during portfolio use. The students' remarks reflected improved positive attitudes towards chemistry and indicated that they had considerably gained from portfolio use leading to improved perceptions and attitudes towards chemistry.

Thembisa reported in her concluding remarks: "My peers said chemistry was difficult to pass, involving a lot of mathematics, and very hard, with teachers being harsh. I believed them and I was afraid of the subject. But now I know that what I was told were all lies. I really enjoyed this subject. It is very interesting. My mind is now set and I will work with whatever I have to pass the subject. I did not enjoy the subject when we started learning about balancing equations because the topic was hard for me then, but after some research, I am glad to announce that I now know everything about it. Everyone was given room to participate. Everyone did a presentation and I can say that this is very good because you cannot forget what you have presented. I was blessed to have a well organized group to work with. Isn't this a very interesting subject? You should study it some time."

Sharon also wrote: "I was nervous and scared. I thought I would be among the first students to drop the subject because I was really afraid of both the teacher and the subject. I now enjoy the subject and I will not drop it. The teacher was strict and fair. I enjoyed the challenging tests, balancing equations. I also liked the fact that our teacher used a rather unique technique, using portfolios. We, the students, reflected on what we did not understand and set targets for ourselves for upcoming tests."

Thomelin complained about the few experiments done but was quick to mention the shortage of resources. She echoed the sentiments about enjoyment, initial negative attitudes and fear of the subject and the teacher. She added that learning through reflections and projects made students improve their learning capabilities.

Identifying students' alternative conceptions

At the beginning of each topic students were expected to record, in their portfolios, the ideas they had about the topic and what they expected to learn in the topics. The science student portfolios became authentic records of students' conceptions and misconceptions. The teacher used the records in the portfolios to identify the students' conceptions and misconceptions prior to and after teaching and learning situations. The prior knowledge and experiences are important factors that influence learning (Ausubel, 1963; Ausubel, Novak and Hanesian 1978; Bordner, 1986; Novak, 2000). One of the common misconceptions encountered was about the expansion and contraction of matter. Students' conception was that atoms increased in size when heated and decreased in size when cooled, rather than the increase and decrease in space occupied by these particles. Another was that students viewed chemical bonds as physical structures (like small sticks joining the two atoms) rather than the attraction between the two nuclei and the electron cloud. The drawing of a line to represent a chemical bond in chemistry tends to reinforce this misconception.

The role of the teacher was to find appropriate teaching strategies that assisted students to fit and integrate their ideas into existing conceptual frameworks. The teacher used cooperative learning in the form of group discussions so that the students could share views. Models were also used in this regard. By using these methods in trying to help students learn, Cain (2000) argued that the misconceptions are sympathetically removed.

Student interviews

The interviews with students were open-ended and each question asked was a follow up and determined by the preceding one. The interviews were held before the students knew the researcher as their teacher but as just one of the science teachers. The interviews appeared like just general talk and the student was quite relaxed with other peers listening in a relaxed mood. They were done outside the classroom and did not seem in any way connected or related to what was to be done in class

Interview sessions with Jimmy and Tracy revealed that they had heard some discouraging ideas about chemistry. Jimmy said, "I can make it. I am prepared to work very hard if they say chemistry is difficult. I heard that calculations could be a problem, I mean mathematics". Tracy hoped to enjoy chemistry even though it was like magic and the reactions were difficult to imagine and that it was normal to drop chemistry at the school.

An analysis of the recorded interviews and the student portfolio conclusions of the two and other students, reveal some transformed students who now enjoy the subject profoundly. Jimmy urged fellow students not to listen to discouraging comments from people, adding that chemistry isn't a difficult subject, but an interesting one.

Table 1. Comparison of the fortnightly test results of the portfolio class and the control

Test Number	1	2	3	4	5
Ave mark for portfolio class (%)	61	79	81	81	69
Standard deviation	12	5	4	4	12
Ave mark for control class (%)	61	68	70	69	59
Standard deviation	11	10	10	11	10
N = 40 for each test/class					

The results for the first test were similar for the two classes, indicative of the similarity of the students' potential capabilities as inferable from grade seven results and the random selection of students into forms 3D and 3E. Results of the last four tests would indicate the effect of the portfolio on performance of students in form 3E.

The usual atmosphere of anxiety exhibited by students when they prepare for tests in chemistry and the usually noticeable sense of resignation and boredom as the students wait for test results were evident form 3D but not for form 3E. Instead, form 3E students showed excitement about the imminent results as if they knew that they had passed and all they were waiting for was confirmation from the teacher. The usual reduction of numbers of students initially enrolled for physical science as students abandon it and opt for human & social biology and integrated science was not witnessed during the project life. No form 3E student ever indicated he/she might want to abandon chemistry for the easier subjects. Instead, a few form 3D students threatened to leave for human & social biology and integrated science if they would never be given chance to take part in the portfolio project. The headmaster gave them assurances and they stayed put. The results of the five tests given during the life of the project vindicate the claims that portfolios create greater responsibility for students' own learning, allow for motivation, diagnosis of strengths and weaknesses, and enhance students' level of achievement.

Summary of the findings of the case study

This simple case study has generated a considerable amount of valuable information concerning the utility of science student portfolio in teaching and learning chemistry at this school. The study was driven by the endeavor to answer the research questions:

1. What is the effect of integrating the science student portfolios on effective teaching and learning of O'Level chemistry?

The portfolio was used as a major instructional tool after it replaced the test exercise book. The test exercise book does not give the students chance to pause and reflect on their work. The portfolio provides opportunities for self directed learning, self reflection, goal setting, research, responsibility for students' own learning, and having their parents or guardians participate in contributing to their learning process and stimulates, excite, challenges, empowers, engages, and retains students in the chemistry class. Thus the portfolio promoted self-directed learning and motivation. Chemistry students paused and reflected on their actions during the learning process, identified grey areas and engaged means to correct misconceptions to improve and achieve self-set goals and test scores. The teacher restricted himself to the post of director of learning while student learning was self driven, fueled by the endeavor to do the best. Students' reflective processes influenced how they grew academically by being able to learn from their past experiences and by their ability to establish strengths and weaknesses during the process of learning. The opportunity for students to take part in goal setting enabled students to set up realistic goals for their preparedness for the next topic or test, stating strategies they would employ to achieve set goals and targets, influencing them to engage in research. In individual research students looked up articles in newspapers and magazines, identifying articles with chemistry issues and summarizing them. Group research was on local chemical industries after which they presented their findings in class, where classmates asked questions leading to unearthing more information about the researched industry, resulting identification of more concepts and issues.

Various stakeholders, including parents and the school administration, were given the opportunity to participate in the learning of the students.

2. What preconceptions do students have about chemistry before they are introduced to the subject?

It emerged that students go into chemistry classes having certain negative perceptions about chemistry. Such perceptions, emanating from fellow students, brothers, sisters and teachers, impact negatively on students learning by instilling fear and negative attitudes towards the subject. The study revealed that students perceived chemistry as a difficult subject because the subject involves a lot of mathematics, a lot of confusing experiments and reactions which are difficult to comprehend. Based on what they heard from their peers, students geared themselves for very tough, strict and unkind teachers. The study tentatively concluded that this fear of the major players responsible for their learning could be a major contributory factor to the student drop out from the subject.

3. How will students, parents and the administration respond to the introduction of science student portfolio as a new instructional and assessment tool?

The initial stages of the integration of the portfolio were difficult to both parents and students. They did not understand why the portfolio was to replace the traditional test exercise book. When they had witnessed how it works all stakeholders (students, parents and the administration) accepted it wholeheartedly as an instructional and assessment tool.

4. What problems will teachers and students encounter in the process of implementing the science student portfolio?

Student problems

Initially the students were not clearly aware of what was expected of them because the early stages involved a lot of activities such as portfolio construction, notes writing, and reflections, all of which were new to them. This led to students prematurely concluding that the workload was excessive. The fears, however, cleared as the portfolios took shape.

Teacher problems

Absenteeism meant that the student was not able to make a reflection on a topic or test he/she had not taken part in. The researcher had to create time for the absentees to be able to take part in subsequent reflection.

The researcher had to content with the large volume of work produced by students in the form of tests, test reflections, topic reflections and to supervise student projects. Inexperience in dealing with such large volume of work was a major challenge.

5. Will the portfolio have effect on the flight of students from chemistry classes?

None of the students had indicated any intention to abandon chemistry studies as has been the case in previous years. Even those in form 3D which was used as a control in this case study were actively seeking to have a chance to be involved in portfolio work. Thus introduction of the portfolio is likely to curb student flight from chemistry.

Conclusion

The portfolio was accepted by students, parents and guardians as a novel idea. It was treated by the administration as if it were new to them but they later admitted that it was widely used as an evaluation tool, at least at teachers' colleges. The acceptance of the use of the portfolio as a teaching and learning tool in this project led to dramatic results that satisfied of all stakeholders. All chemistry teachers to whom the researcher talked informally in connection with the portfolio admitted that it was potentially an effective evaluation tool but it was not as widely used, even as an evaluation tool, because it was time consuming. They also agreed that it could satisfy the need for effective chemistry teaching and learning approaches that stimulate, excite, challenge, empower, and engage students; that the portfolio may be instrumental in improving teaching and learning as it might challenge chemistry educators to change their teaching strategies and provide real world learning opportunities for students; that it would empower the students to develop a sense of ownership of their chemistry learning, nurture students, foster a positive self-concept of learning, and involve students in self-reflection and in determining and setting individual goals.

They also agreed that educational planners, policy makers, curriculum developers and national examiners might use portfolios to get useful information for their understanding of what is on the ground in respect of how chemistry is taught and learnt in schools. They also felt that portfolio marks could be incorporated in the final examinations as coursework as it contains holistic information about students' performance.

If the portfolio has the potential for this wide acceptance, why not use it and give educators the opportunity to abandon present chemistry teaching and learning approaches in favor of science student portfolios; thus shifting towards the constructivist learning model which is problem based learning resulting in constructions of meaning by students, a move that is amenable to meaningful learning?

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