Teaching Science Through Multi-sensory Approach

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Abstract

This action research study focuses on how multi-sensory learning helps the Secondary Three triple-pure-science (namely, Biology, Chemistry, and Physics) students of Bedok North Secondary School (BNSS) to improve their application of science knowledge. This is a qualitative and quantitative study involving 40 students from an experimental class. The students were taught basic knowledge before setting off to embark on their respective projects. This research study lasted 2 terms (six months) and involved an integration of various science disciplines. Data was gathered from sources including pre- and post- perception surveys, students’ and teachers’ reflections. Problem Based Learning (PBL) was adopted as a tool to enhance the knowledge acquired.

Introduction

In Bedok North Secondary School (BNSS), many students were found to be struggling with Science Application Questions. Most triple-science students were unable to make connections between isolated facts and also not being able to apply their knowledge in new complex situations. Hence, they could not answer the Science Application Questions well during Science tests and examinations. Prompted by this emergent need in school, our team embarked on an action research journey to explore the use of Problem-based Learning (PBL) in helping these students. As pointed out by Dick (2001), action research achieves change through its participative approach and enables this research study to be conducted by being responsive to the situation. During the action research journey, the research team adjusted our teaching approach and took into account the growing understanding of PBL. Our action research journey comprised a series of four action research cycles as described in the following sections.

Action Research Cycle One
Perform Literature Review

In this action research cycle, we performed literature review on two key themes, namely, multi-sensory approach and Problem-based Learning (PBL). Multi-sensory refers to any learning activity that includes the simultaneous use of two or more sensory modes to absorb and analyse information. An advantage of multi-sensory approach is that it engages individuals with different learning styles, for example, the ‘visual learners’ and ‘auditory learners’. Treichler (1967) stated ‘People generally remember 10% of
what they read, 20% of what they hear, 30% of what they see, and 50% of what they see and hear’. The human brain has evolved to learn and operate in natural environments in which behavior is often guided by information integrated across multiple sensory modalities. Therefore, unisensory-training protocols used for skill acquisition in adults offer unnatural settings and do not tap into multi-sensory learning mechanisms that have evolved in humans for producing optimal behavior in the naturally multi-sensory environment. According to Shams and Seitz (2008), multi-sensory-training protocols, as opposed to unisensory protocols, approximate natural settings better and, in turn, produce greater and efficient learning. However, the extent to which this facilitation occurs depends on the efforts put in by teachers.

The principle of ‘dual coding’ (Clark and Paivio, 1991) indicates that information entering the system through multiple processing channels helps circumvent the limited processing capability of each individual channel and, thus, greater total information can be processed when spread between multiple senses (using more channels). Related research indicates that multimodal processing reduces cognitive load because information from different modalities can be more easily chunked into short-term memory and used to build long term representations, (Bagui, 1998). Mayer (2001) states that additional information within the same modality can saturate one channel to prevent further input of information. Worst, should the saturated materials be incoherent with the core concept, it caused a “misinterpretation” to be registered within the mind of that individual. For example, Bahrick and Lickliter (2000) showed that 5-month-old infants could discriminate visually presented rhythms only if they were habituated with auditory–visual presentations of the rhythm and not when habituated with visual-only or auditory-only presentations of rhythm.

Researchers have also found that there exist persistent shortfalls in students’ understanding and the passive knowledge across all grades (Garder, 1991). Most teachers adopt conventional teaching that is based on verbal explanations or visual demonstrations of a procedure or skill that are coupled with drill and practice of that procedure or skill by the students. Goodlad (1984) found that students rated physical education, fine arts, or industrial arts classes as most interesting because they actually got to do something. They were actively involved in the assigned tasks.

With regards to the second theme of this research study, PBL is put forth by Barrows (2002) and Savery (2006) as an instructional and curricular learner-centered approach that empowers learners to conduct research, integrate theory and practice, and apply knowledge and skills to develop a viable solution to a defined problem. According to Hmelo-Silver, (2004), PBL produces the target outcomes of deep content learning, increased problem-solving ability, and increased self-directed learning. Moreover, both Walker and Leary (2009) and Strobel and van Barneveld (2009) determined that PBL is favored in studies that requires assessments for measuring application of knowledge and principles.

As explained in the work of Glassman (2001) and that in Wikipedia (2001), PBL is a student-centered instructional strategy in which students collaboratively solve problems and reflect their experiences. Characteristics of PBL include the followings:

- Learning is driven by challenging, open-ended, ill-defined and ill-structured, practical problems.
- Students generally work in collaborative groups. Problem based learning environments may be designed for individual learning.
- Teachers take on the role as “facilitators” of learning.
• Instructional activities are based on learning strategies involving semantic reasoning, case based reasoning, analogical reasoning, causal reasoning, and inquiry reasoning. These activities include creating stories; reasoning about cases; concept mapping; causal mapping; cognitive hypertext crisscrossing; analogy making; and question generating.

Relevant problems are introduced at the beginning of the instruction cycle to serve as the context and motivation for the learning that follows. It is always active and usually involves collaborative or cooperative learning. Students get the opportunity to discuss and conduct a self-talk with their peers and facilitators in order to digest and internalise the problems this is also described in the heutogogical process of learning.

Stewart Hase and Chris Kenyon (2000) suggest that Heutagogy is concerned with learner-centered learning that sees the learner as the major agent in their own learning, which occurs as a result of personal experiences. It emphasizes that adults learn, when they are ready. It assumes that people have the ability to learn continuously throughout life and in real time and is accomplished through various interactions with one’s environment. Heutagogy addresses issues about human adaptation as the world enter the new millennium and these issues are posed as problems in PBL for students to handle.

Francis J. Gardella in his book entitled “How children learn mathematics” also suggests that the learner needs to move from a concrete stage, proceed through a connecting stage before arrive at a symbolic stage. According to Gardella, it is the language of understanding or personal experience that the learner brings into the classroom which allows the learner to develop understanding of mathematics.

It is pertinent that in the literature reviews mentioned above, students in their natural environment will need to be given autonomy and collaboration opportunity for them to construct their own learning and elevate their motivation to learn. Students are encouraged to take responsibility for their group and organize and direct the learning process with support from a teacher. This in turns has prompted us to enter the second action research cycles for deriving our Research Questions.

**Action Research Cycle Second**
**Derivation of Research Questions**

The world today is no place for people who are unprepared and inflexible in their jobs. This boils down to equipping students with the skills of knowing how to learn in order to prepare them for a turbulent working environment. To facilitate the learning process, BNSS incorporates a multi sensory approach in the science lesson. This involves the introduction of a project based on PBL to provide students an opportunity to use their multiple sensors as different acquisition modes for a given set of information. The purpose is to integrate the Biology, Chemistry and Physics topics into their daily environment through the usage of various senses and to see “science as alive”. The tasks also aimed to sharpen the students’ scientific skills in observation, measurement, and interpretation of data, investigation, reasoning and problem-solving.

A few learning set sessions were conducted among ourselves before we arrived at the following two research questions, namely,

*Does the adoption of multi-sensory learning enhance student engagement in the learning of secondary three triple-pure-sciences?*

*Does the adoption of multi-sensory learning through PBL enhance student cognitive achievement in the learning of secondary three triple- pure-sciences?*
There are two categories of Secondary Three students in our school. First category is an Express Class that requires its students to complete their secondary school education in four years. The second category is the Normal Class that requires its students to complete in five years. In general, Express Class students are academically more capable than their fellow students from Normal Class. Our team preferred to work on Express Class due to the fact it was easier for us to insert our intervention into their usual lessons without causing unwanted disruptions to this brighter group of students. Two classes of Secondary Three (Sec 3) Express students with each consisting of 41 students were selected for this research study. Most of the Secondary Three students are fifteen years old. They have been in the education system for eight years since primary one. One class was chosen to be the experimental group, while the other was chosen to be the control group. Both groups have equal number of students. Two out of three teachers taught both classes. The following table 1.1 shows a summary of the students profile from the two classes.

<table>
<thead>
<tr>
<th></th>
<th>Experimental group</th>
<th>Control group</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total No of students</strong></td>
<td>41</td>
<td>41</td>
</tr>
<tr>
<td><strong>Sex Ratio</strong></td>
<td>18 M, 23 F</td>
<td>17 M, 24 F</td>
</tr>
<tr>
<td><strong>Academic Ability</strong></td>
<td>Same Ability</td>
<td>Same Ability</td>
</tr>
<tr>
<td><strong>Biology Teacher</strong></td>
<td>Ms Lenny</td>
<td>Ms Lenny</td>
</tr>
<tr>
<td><strong>Chemistry Teacher</strong></td>
<td>Mdm Haliza</td>
<td>Mdm Haliza</td>
</tr>
<tr>
<td><strong>Physics Teacher</strong></td>
<td>Ms Faizah</td>
<td>Mr Lau</td>
</tr>
</tbody>
</table>

Table 1.1. Students profile from the two classes.

The project was divided into 4 stages, namely, planning, training, execution and monitoring. In planning stage, the teachers worked as a team for aligning project tasks to the scheme of work that were consistent and relevant to the syllabus and selected real world context. The project tasks were carefully prepared to ensure that students have the opportunity to exercise at least two sensors simultaneously. Students worked in groups and had the option to choose only one project task to collaborate on.

Teachers were trained and exposed to the basic knowledge of accessing research tools such as the real time data logger or recorder. As for the students, teachers designed lessons to equip pupils with basic knowledge and skills for their investigative learning and reflection. The teachers also looked up and included new ideas and technologies during the course of activity for helping the students to solve the assigned problem. Students were encouraged to discuss on any new findings and provide support for
Students had the freedom to choose their own group mates. The students took on various roles such as group leader who set goals and direction, motivated the group and ensured all were on task. The assistant leader was also appointed to support the team, especially when the leader could turn up in class. An administrator safe-kept all the research materials used by the team. A recorder was also assigned to document all the discussions and findings. To develop their communication skills, all the team members had to present their findings to the class.

Teachers covered basic content knowledge needed by the assigned task. The teachers used visual and auditory aids to enhance learning. The students also needed to do additional research in solving the assigned task. This appealed to the kinaesthetic and tactic learners. They were given the availability of computers to do their further research. The teacher discussed with their students on the assigned tasks and act as facilitators. The teachers adopted Socratic questioning in class to direct students to focus on critical thinking and changing perspectives. Teacher also ensured each student share ideas within the group. Besides, students were given rubrics derived by teachers to be used as a guide where necessary during the project.

As part of their cognitive development, the students had to reflect on their projects and compile a report detailing the processes they had to undergo prior to their derived solutions - this was intended to help students evaluate their learning. As part of the monitoring process, data in the form of surveys were collected to provide the teachers with feedback for further improvements in the future projects. A post-test was conducted to assess the cognitive achievement of students.

**Action Research Cycle Fourth Data Analysis**

To ensure the two groups of students selected for study were equivalent, previous achievement scores in the secondary two end of year examination were adopted to compute the Standard Mean Difference (SMD) between the two groups. The SMD for the Semester Assessment 2 (SA2) scores were found to be 0.09, implying that the effect size is small. The following Table 1.2 shows an analysis of the mean and standard deviation of the two classes.

<table>
<thead>
<tr>
<th>Scores</th>
<th>Group Type</th>
<th>Mean</th>
<th>SD</th>
<th>Difference</th>
<th>SMD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project Group (N=41)</td>
<td>64.9</td>
<td>11.60</td>
<td>1.0</td>
<td>0.09</td>
<td></td>
</tr>
<tr>
<td>Regular Group (N=41)</td>
<td>63.9</td>
<td>14.0</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 1.2. Analysis of the mean and standard deviation of the two classes.

**Means of Measures**

The adopted research method comprised of quantitative and qualitative methods. The quantitative research methods consisted of post-test questions conducted at the end of Term 4. The consolidated...
scores were used to compare the performance between the project group and the comparison group. A rubric was utilised as a feedback tool for students on their project. The qualitative research methods used perception survey. Perception survey was administered to both project groups before and after the experiment to register any change that the groups have gone through.

Data Analysis

The overall scores in science in year-end examination for the two groups were analyzed separately using independent t-test. Information was also collected through the surveys conducted.

Results and Discussions

The project commenced at the end of term 1 and the students presented their findings at end of term 3. T-test was used to check the equivalence between the project and regular group. The secondary two SA2 science results were used as the input data. This is shown in Table 2.1. There was no significance difference found using the t-test in Table 2.1 below and therefore the two groups were equivalent.

<table>
<thead>
<tr>
<th></th>
<th>Project Group</th>
<th>Regular Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean of SA2</td>
<td>64.9</td>
<td>63.9</td>
</tr>
<tr>
<td>P(T&lt;=t) one-tail</td>
<td>0.48</td>
<td></td>
</tr>
</tbody>
</table>

Table 2.1: t-Test of Two-Sample Assuming Equal Variances

In a comparison of year-end examination results gathered in 2008 and 2009 Secondary Three Express cohorts, both groups have no significant difference (p > 0.05) and hence are equivalent.

<table>
<thead>
<tr>
<th></th>
<th>Regular Group</th>
<th>Project Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean Marks</td>
<td>72</td>
<td>87</td>
</tr>
<tr>
<td>p value</td>
<td>0.06</td>
<td></td>
</tr>
<tr>
<td>Significance (p&lt;=0.05)</td>
<td>No</td>
<td></td>
</tr>
</tbody>
</table>

Table 2.2: Independent t-test results of regular and project groups.

This implies that the intervention had no significant impact on the Project and Regular groups. But as seen in Table 2.2 above, there is a slight improvement of about 15 units in the mean marks. Extraneous variables could have contributed to the improvement in the mean mark. This could also be attributed to the difference in the physics teacher teaching both classes. The Physics teacher for the 2009 Secondary Three cohort also acted as the Form teacher of the class. As a result of more time spent with the class, the teacher could have built better rapport with the students, resulting in an improved mean score in science. In addition, the project group had a slightly higher T-score of 205 as compared to the regular group with a T-score of 204. The analysis of Secondary Three year-end examination results for 2007, 2008 and 2009, shows a positive trend for the percentage passes. Graph 1 below shows the positive trend seen over the past three years for all the science disciplines scored by the triple pure science class. The intervention was introduced in 2009 and there was already a slight improvement shown in 2008.
From the feedback obtained through the open-ended responses in the surveys and reflections, almost 80% of the students indicated a preference for the multi-sensory approach through the adoption of PBL. They appreciated the different way of acquiring the scientific knowledge and skills. They expressed their interest in the autonomy of crafting their own learning and interaction during the discussion process. The discussion process had helped them to have a better grasp for the subjects. During consultations, the facilitators were very helpful in identifying the various groups’ weaknesses and re-directing the groups to make further improvements to their solutions. Facilitators observed that the stronger team members were able to use their ‘common lingo’ to communicate and teach the rest of the team members and this had helped to accelerate the learning process of the whole group. The students were able to consider the feedback given and picked up problem-solving and self-directed learning skills from there. They shared that it was a good approach that the facilitators did not give them the answers but instead provided them with provoking questions to let them think and explore areas that they have not thought of. In a typical classroom prior to this study, the students’ creativity and interactions were limited by the rigid curricular time table.

The students also employed multi-sensory approach to process information. They used auditory and visual mode of learning when they discussed and critiquized ideas. The kinaesthetic and tactic learners were able to construct their prototypes and build upon it. Students were more engaged as they were more aware of the relevance of science in their lives. They felt their learning was more authentic. To them, acquiring the relevant knowledge at their own comfortable environment and pace was meaningful as they get to apply and conceptualise the ideas immediately. The target was tangible. In fact, some of them went further to do their own research even after the project has ended. The project has developed students to be more enthusiastic in the normal science lessons.

However, duration was the reason mentioned by minority of the students who claimed that the project did not increase their level of engagement. They needed more time to come up with a good solution. The difficulty lies in juggling of time with the other subjects as they felt that the project was time-
consuming. Others indicated that they would like to have more challenging tasks than those used in this research study. The teachers’ reflected that the multi-sensory approach through PBL benefited even the quiet ones, especially in building up their confidence and communication skills. Most students welcomed the change in the mode of learning although some needed more time to adjust to it.

**Recommendations**
A pre and post perception survey using PETALSTM instrument could be conducted to provide a more accurate comparison and response to the level of engagement of the intervention introduced. The PETALSTM instrument could provide a holistic review of the different dimensions that may contribute to the improvement of students’ learning mode and environment.

A reliable data logger apparatus would be useful for investigation process. Due to encountered technical issues, experiments were disrupted and broke chain of thoughts during the testing stage especially when time was a crucial factor. Subscribing from companies that could deliver good support and product would definitely be beneficial to the groups.

March holiday is the recommended duration for such project when students have time to execute the assigned task. Besides, this will also free the students to concentrate on their mid year examination in term two. Future projects should also exclude the involvement of animals such as fishes due to ethical reasons. In one of the projects that requires student to build an aquarium, many fishes died due to lack of care. Future collaborations could also be extended to the other subjects such as between physics and geography instead. This could bring greater relevance to the topics in the syllabus.

**Conclusion**
Students exposed to the intervention showed a greater interest and potential to learn at their own pace. The multi-sensory approach has established a natural environment for them to process knowledge through their own mode of preference. Teachers play a vital role in helping the students to ask questions they have not thought of, thereby developing their thinking and reflection skills. Students’ capability is also increased through the interactions and discussions with their peers. Although teachers may intervene at certain junctions, not all the students were able to comprehend the pointers. The self-talk using their own experiences and language between the team members has enabled the rest of the team mates to fully understand and move towards their learning goals.
However, the increased engagement and confident level in students do not have a significant translation to their academic achievement as discussed earlier. Teachers may still need to consider that time is still a factor for students to juggle between the project and the other subjects.
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- Science Teachers

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