THE EFFECT OF MICROSCALE CHEMISTRY EXPERIMENTATION ON STUDENTS’ ATTITUDE AND MOTIVATION TOWARDS CHEMISTRY PRACTICAL WORK

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Microscale chemistry is an approach to conducting chemistry practicals which can help overcome increased concerns about environmental pollution problems as well as rising laboratory costs. It is accomplished by using miniature labware and significantly reduced amounts of chemicals. This paper reports on students’ attitudes and motivation towards chemistry laboratory work before and after performing microscale chemistry experiments. Students’ perceptions of the microscale chemistry experimentation are also reported. Students were exposed to ten microscale chemistry experiments in the chemistry laboratory for a period of 8 weeks. In general, students have a positive view of microscale chemistry experiments. However, findings from the survey conducted showed no significant difference in attitude and motivation before and after the treatment.

Keywords: Microscale chemistry, students’ attitude, motivation, chemistry practical work
Introduction

One of the unique features of effective science teaching is laboratory work. It is a unique learning environment that is effective in helping students construct their knowledge, develop logical and inquiry-type skills and develop psychomotor skills. Laboratory work also has great potential in promoting positive attitudes and providing students with opportunities to develop skills regarding cooperation and communication (Hofstein, 2004). Part and parcel of learning chemistry is carrying out laboratory practicals. From an educational point of view, chemistry without laboratory work was seen as a body of factual information and general laws which conveyed nothing of lasting power to the mind (Layton, 1990).

The science curriculum in the Malaysian educational system is designed for students from primary to the secondary levels. The science curriculum comprises three core science subjects and four elective science subjects and is formulated based on the needs of the nation as well as global scientific requirements. The core subject is science at the primary, lower secondary and upper secondary levels. Elective science subjects are offered at the upper secondary level and consist of biology, chemistry, physics, and additional science. The elective science subjects prepare students who are more scientifically inclined to pursue the study of science at post-secondary levels. This group of students may take up careers in the field of science and technology and thus play a leading role in nation development.

The chemistry curriculum aims at producing active learners. To this end, students are given ample opportunities to engage in scientific investigations through hands-on activities and experiments. The inquiry approach, incorporating thinking skills, thinking strategies and thoughtful learning, should be emphasised throughout the teaching-learning process. The science laboratory has always been regarded as the place where students should learn
the process of science. Ideally, each student should be wholly responsible for conducting the experiments from start to finish. However, research has shown that teachers favoured conducting practical activities in groups (Sharifah & Lewin, 1993). They reported that of the teachers surveyed, 54 percent reported group sizes of 4 or 5 students per group. Direct observation of classes noted a range of 1 to 7 students per group. The large group size limited active participation to 2 to 3 students per group, leaving the others as passive onlookers. This resulted in low level acquisition of scientific skills and knowledge among the students. Students require the hands-on practical and personal laboratory experiences to acquire the science process skills.

Other problems associated with practical work in schools include the lack of facilities. One case study revealed that in general, equipment was adequate for group work in all schools for group sizes of 4 to 5 students (Sharifah & Lewin, 1993). Research on implementation of laboratory work assessment, PEKA (Pentaksiran Kerja Amali / Practical Work Assessment), indicated that the constraints which hinder the effectiveness of implementing the PEKA programme in classrooms were lack of apparatus and materials, students’ negative attitudes, passiveness and lack of cooperation (Mingan, 2001). This type of assessment requires students to gain manipulative skills by doing practical work individually. Teachers also appeared to favour group activity, rather than individual work, since there was less preparation and washing up needed and it was easier to maintain discipline and control among students (Sharifah & Lewin, 1993).

One solution to overcome problems associated with practical work in chemistry would be through the implementation of microscale chemistry. Microscale chemistry is a laboratory-based, environmentally safe, pollution-prevention approach accomplished by using miniature glassware and significantly reduced amounts of chemicals (Singh, Szafran & Pike, 1999). It can use as little as 25
to 100 milligrams of solids and liquids can be reduced to between 100 to 200 microlitres. Precision or accuracy of experiments is not compromised. Findings from several studies indicated that the microscale approach has been shown to be particularly effective in wet analytical chemistry techniques and this technique yielded data of comparable accuracy and precision to the macroscale technique (Singh, Pike & Szafran, 1995, Singh, McGowan, Szafran & Pike, 2000 and Richardson, Stauffer & Henry, 2003). It is recognised as small scale chemistry by the International Union of Pure and Applied Chemistry (Bradley, 2002). Teachers can use it as a tool to design new lab activities that could be integrated into their everyday classrooms (Cooper, Conway & Guseman, 1995).

Among the benefits of microscale chemistry are improved safety, cost and time savings, environment-friendliness, pollution prevention, more adaptable equipment and also enhanced chemistry learning (McGuire, Ealy & Pickering, 1991, Yazzie, 1998, Bradley, 1999, Singh et al., 1999, Kelkar & Dhavale, 2000, Vermaak & Bradley, 2003, Tallmadge, Homan, Ruth & Bilek, 2004). It is one of the ways in which chemical education can contribute towards sustainable development. Microscale experiments provide hands-on activities and personal experience since all the students would be able to do experiments individually. Hence, microscale chemistry experiments are seen as a viable alternative to encourage teachers as well as students to want to do practical work in chemistry. Bradley (1999) reported that the development of the microchemistry system is based on such equipment which is easy for individual students to use and convenient for teachers to implement in schools.

**Study Design**

In this study, a ‘one group pre-test post-test design’ was used. The study was conducted with 75 Form Four students (three science classes) to expose them to hands-on practical activities and ideas on pollution prevention through microscale experimentation. The
average age of the students is 16 years old. Pre and posttests were conducted before and after the treatment. A questionnaire on attitude and motivation towards chemistry laboratory and chemistry learning was administered to all the students prior to the treatment.

Figure 1. Microscience kit.

During the treatment, all students were required to do the microscale experiments individually using a microscale chemistry kit. The students carried out 10 experiments that have been developed at the School of Chemical Sciences, Universiti Sains Malaysia according to the Form Four KBSM (Kurikulum Bersepadu Sekolah Menengah / Integrated Curriculum for Secondary Schools) chemistry syllabus (Abdullah, Ismail & Mohamed, 2005). Forty experiments have been designed using the Microscience Kit (RADMASTE Centre, South Africa) and also small scale glassware. Figure 1 shows the apparatus.
from the Microscience kit which was used in this study. The kit uses a plastic microwell plate with two sizes of microwells. Solids are handled with plastic microspatulas while liquids are handled using propettes and syringes.

The topics chosen for the study are electrochemistry and acids and bases – two topics in the Form Four chemistry curriculum (Curriculum Development Center, 2004) which are considered difficult by the students. The experiments are listed in Table 1.

Table 1
List of Experiments

(i) Investigation on the electrolysis of aqueous copper(II) sulphate solution and sodium hydroxide solution.
(ii) Investigating the effect of types of electrodes on products of electrolysis.
(iii) Purification of copper.
(iv) Electroplating of an iron nail with copper.
(v) Showing the production of electricity from chemical reactions in a simple Voltaic cell.
(vi) Constructing the electrochemical series based on the potential differences between two metals in an electrochemical cell.
(vii) Constructing the electrochemical series using the principle of displacement of metals.
(viii) Measuring the pH values of solutions used in daily life.
(ix) Measuring the pH values of acidic and basic solutions with similar concentrations.
(x) Determining the end point in the titration of hydrochloric acid and sodium hydroxide solution using an acid-base indicator.

Practical or laboratory classes were conducted every week for a duration of two and a half months. In the curriculum, chemistry is given four periods per week. The teacher used two periods for teaching the concepts related to a topic and another two periods for conducting microscale experiments related to the concepts. All the
classes were taught by the same teacher who was trained to conduct the microscale experiments by the researcher. The students were informed that their responses to the survey were confidential. After the treatment, the same attitude and motivation questionnaire was administered to all the students with an additional 9 items regarding perceptions towards microscale chemistry experiments. The students were also asked to give open-ended comments in order to obtain their perceptions and feedback about microscale chemistry experiments. This study was conducted to answer the following questions:

1. Is there any significant difference in student attitude towards chemistry laboratory work before and after doing microscale experiments?
2. Is there any significant difference in student motivation before and after doing microscale experiments?
3. What were the students’ perceptions about microscale chemistry experimentation?

A paired sample t-test was used to test for significant differences for attitudes and motivation before and after treatment with $p < 0.05$ being considered as significant. The data for perceptions towards microscale experiments were reported in terms of frequencies and mean values for each individual item. Open-ended comments were analysed and reported qualitatively.

**Attitude Survey**

The questionnaire, entitled *Attitude Towards Chemistry Laboratory Work*, developed and validated by Hofstein, Ben-Zvi & Samuel (1976) and modified by Vermaak (1997) was used. The 5-point Likert scale expressed in terms of ‘strongly disagree’, ‘disagree’, ‘not sure’, ‘agree’ and ‘strongly agree’ was used. To score the scale, the response options were coded 1, 2, 3, 4, or 5 according to the responses from strongly disagree to strongly agree. Reverse coding was used.
for negative items to compare the mean factor values (Table 4). The pretest consisted of 28 items on chemistry laboratory work with a combination of positive and negative statements. The items are divided into five factors related to students’ interests in doing practicals in chemistry, enjoyment of performing practicals and handling equipment, practical aspects of laboratory work, how students consider laboratory work as ‘a way of learning’ and environmental value of practical work. The posttest consisted of 28 similar items as the pretest and 9 additional items on perceptions towards microscale chemistry experiments. Open comments were also asked from the students regarding chemistry laboratory work and microscale chemistry experimentation.

**Motivation Survey**

For the motivation survey, the *Motivated Strategies for Learning Questionnaire* (MSLQ) developed and validated by Pintrich, Smith, Garcia & McKeachie (1993) was used. Again, the 5-point Likert scale ‘strongly disagree’, ‘disagree’, ‘not sure’, ‘agree’ and ‘strongly agree’ was used. For scoring purposes, the response options were coded 1, 2, 3, 4, or 5 from strongly disagree to strongly agree. Reverse coding was used for negative items to compare the mean factor values for the motivation inventory (Table 6). The survey consisted of 30 items divided into six scales: intrinsic goal orientation, extrinsic goal orientation, task value, control beliefs of learning, self-efficacy for learning and performance and test anxiety. The same questionnaire was administered during the pre and post test.

A pilot test was conducted for both questionnaires on twenty five Form Four students to assess the suitability and clarity of items. The feedback obtained from students in the pilot test were used to modify identified weaknesses in the items. The reliability estimates for subscale internal consistency for both attitude and motivation questionnaire were obtained (Table 2). The reliability values for
the attitude, perception and motivation scales varied from 0.38 to 0.85.

Table 2
Reliability Estimates for Attitude and Motivation

<table>
<thead>
<tr>
<th>Instruments</th>
<th>Cronbach’s α reliability coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Attitudes</strong></td>
<td></td>
</tr>
<tr>
<td>Factor 1: Students’ interest in doing practicals in chemistry</td>
<td>0.53</td>
</tr>
<tr>
<td>Factor 2: Pure attitudinal factor, demonstrates the pupils’ enjoyment in performing practicals, handling equipment and chemicals</td>
<td>0.83</td>
</tr>
<tr>
<td>Factor 3: Practical aspects of lab work</td>
<td>0.60</td>
</tr>
<tr>
<td>Factor 4: Lab work as a way of learning</td>
<td>0.63</td>
</tr>
<tr>
<td>Factor 5: Environmental values of chemistry practical work</td>
<td>0.79</td>
</tr>
<tr>
<td>Perception towards microscale experiments</td>
<td>0.80</td>
</tr>
<tr>
<td><strong>MSLQ</strong></td>
<td></td>
</tr>
<tr>
<td>Intrinsic goal orientation</td>
<td>0.38</td>
</tr>
<tr>
<td>Extrinsic goal orientation</td>
<td>0.69</td>
</tr>
<tr>
<td>Task Value</td>
<td>0.76</td>
</tr>
<tr>
<td>Control Belief of Learning Scale</td>
<td>0.78</td>
</tr>
<tr>
<td>Self-Efficacy for Learning and Performance</td>
<td>0.85</td>
</tr>
<tr>
<td>Test Anxiety</td>
<td>0.58</td>
</tr>
</tbody>
</table>

**Results and Discussion**

Table 3 shows the results of the students’ responses to all items which were categorised into five factors. In terms of interest in doing chemistry practicals (Factor 1), most of the students were in agreement that performing experiments can increase their interests
and perceived that without practicals, learning chemistry was uninteresting. These findings were also supported by several researchers who reported that laboratory work is an important medium for promoting students’ interest in chemistry studies and also enhancing their attitude towards learning in chemistry laboratory (Ben-Zvi, Hofstein, Samuel & Kempa, 1976; Hofstein & Lunetta, 1982; Okebukola, 1986; Thompson & Soyibo, 2002). However, there are no significant differences for all items in Factor 1 between pre and post tests in this study. This indicates that the microscale approach did not affect students’ interest in doing chemistry practicals. These students had just entered their science classes (Form Four is equivalent to grade 10) and therefore they were eager to do experiments, no matter what treatment were used. Hofstein, Ben-Zvi & Samuel (1976) had shown that grade 12 students who were older were less stimulated by laboratory work.

Table 3
Student Responses to the Scaled-Responses Attitude Survey

<table>
<thead>
<tr>
<th>Item</th>
<th>Mean</th>
<th>Pre test</th>
<th>Post test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factor 1: Students interest in doing practicals in chemistry</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.1 Performing experiments in chemistry increases my interest in the subject.</td>
<td>4.04</td>
<td>4.04</td>
<td></td>
</tr>
<tr>
<td>4.15 Learning chemistry without practicals is uninteresting.</td>
<td>4.10</td>
<td>3.96</td>
<td></td>
</tr>
<tr>
<td>4.19 Chemistry practical work is very tiring.*</td>
<td>1.70</td>
<td>1.78</td>
<td></td>
</tr>
<tr>
<td>4.21 The more time I spend on chemistry practical work the greater my interest.</td>
<td>3.80</td>
<td>3.79</td>
<td></td>
</tr>
</tbody>
</table>
Factor 2: Pure attitudinal factor, demonstrates the pupil’s enjoyment of performing practicals, handling equipment and chemicals

<table>
<thead>
<tr>
<th>Question</th>
<th>Score for 1</th>
<th>Score for 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.2 Practical work in chemistry is boring and routine.*</td>
<td>1.78</td>
<td>1.95</td>
</tr>
<tr>
<td>4.4 I enjoy seeing things for myself during practicals.</td>
<td>4.60</td>
<td>4.47</td>
</tr>
<tr>
<td>4.12 I enjoy handling equipment and chemicals.</td>
<td>4.09</td>
<td>4.23</td>
</tr>
<tr>
<td>4.16 Performing chemistry experiments is too complicated for me.*</td>
<td>2.12</td>
<td>2.08</td>
</tr>
<tr>
<td>4.20 I am looking forward to the next chemistry experiment.</td>
<td>3.90</td>
<td>3.98</td>
</tr>
<tr>
<td>4.23 I prefer lessons given by the teacher because practical work is unorganised.*</td>
<td>2.55</td>
<td>2.30</td>
</tr>
<tr>
<td>4.25 I do not like chemistry experiments because the observations are never exact.*</td>
<td>1.88</td>
<td>1.98</td>
</tr>
<tr>
<td>4.26 With the help of practical work chemistry come alive.</td>
<td>4.09</td>
<td>4.03</td>
</tr>
</tbody>
</table>

Factor 3: Some practical aspects of lab work

<table>
<thead>
<tr>
<th>Question</th>
<th>Score for 1</th>
<th>Score for 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.3* Performing experiments in chemistry is a waste of money.</td>
<td>1.54</td>
<td>1.62</td>
</tr>
<tr>
<td>4.6 More time should be devoted to chemistry practical work.</td>
<td>3.36</td>
<td>3.39</td>
</tr>
<tr>
<td>4.8 If I do many experiments myself, I will do better in the final exam.</td>
<td>3.02</td>
<td>3.06</td>
</tr>
<tr>
<td>4.10 Periods for practicals are a waste of time.*</td>
<td>1.59</td>
<td>1.64</td>
</tr>
<tr>
<td>4.13 Viewing videos or television which show experiments being performed is better than doing the experiment myself.*</td>
<td>2.22</td>
<td>2.06</td>
</tr>
<tr>
<td>4.17 Practical work remains important even after the novelty wears off.</td>
<td>3.67</td>
<td>3.46</td>
</tr>
</tbody>
</table>
4.22 It is sufficient for one pupil to perform the experiment and the rest to get the results from him.* 1.58 1.57
4.24 There is no sense of redoing experiments that scientists have done in the past.* 1.80 1.94

**Factor 4: How students consider lab work as a way of learning**

4.5 I prefer doing experiments myself to watching the teacher demonstrate them. 3.61 3.76
4.7 I learn more when I do the experiment myself. 3.14 3.54
4.9 I prefer reading my chemistry book to doing experiments.* 2.33 2.22
4.11 Chemistry can be learnt and understood without practicals.* 1.77 1.90
4.14 I understand basic concepts better when I perform the experiment myself. 3.12 3.60
4.18 Performing experiments help me understand the theoretical material better. 4.11 4.06

**Factor 5: Environmental value of chemistry practical work**

4.27 Chemistry practical work too relevant with my daily life. 3.46 3.53
4.28 Doing chemistry practical work can apply chemistry knowledge in solving problems. 3.86 3.67

*Statements formulated negatively
Rating was on a scale of 1 (Strongly disagree) to 5 (Strongly agree)

Factor 2 comprises pure attitudinal factors demonstrating the students’ enjoyment of performing practicals, handling equipment and chemicals, seeing things for themselves and looking forward to practicals. The data showed that students enjoy handling equipment and chemicals and seeing things during practicals since the responses for both items ranged between 4.09 to 4.60. In fact,
the students were not in agreement that chemistry experiments are too complicated and unorganised. These findings are supported by Tobin (1990) who suggested that meaningful learning is possible in the laboratory if students are given opportunities to manipulate equipment and materials in order to be able to construct their knowledge of phenomena and related scientific concepts.

Responses for practical aspects in lab work (Factor 3) showed that the students thought that more time should be devoted to practical work but were uncertain that doing experiments individually would improve their performance in their final exams since the responses were close to ‘3’ for the pre and posttests. The data also indicated that they did not agree that performing experiments were a waste of money and time and perceived that doing experiments individually is better than viewing the experiments on video or on television.

Students’ responses for the items in Factor 4 ranged between 3.14 to 4.11 (positive items) and 1.77 to 2.33 (negative items). This indicates that students considered lab work as a way of learning. They preferred doing experiments individually compared to watching demonstrations and perceived that they can learn more and understand the basic concepts better by doing experiments individually. During the treatment in this study, the microscale experiments provided the students opportunities to do experiments individually. Bradley (2001) claimed that practical work should involve active student participation.

In terms of environmental values (Factor 5), the students slightly agreed that practical work is relevant to their life and in solving problems since their responses were closer to 3.5 to 4. In fact, the mean score for item 4.27 that focused on whether practical work was relevant to their daily life increased in the posttest. Yazzie (1998) reported that Dr. Mono Singh of the National Microscale Chemistry Centre had stated that students who were trained using microscale
chemistry techniques changed their views on the environment since microscale experiments are safer and more environmental friendly. Tallmadge, Homan, Ruth & Bilek (2004) also stated that the application of microscale chemistry experiments provides the opportunity to raise awareness of the values of environmental stewardship into pre-college students regardless of the field in which their interests lie.

Although no significant difference was evident among the factors (Table 4), the mean values for several items in certain factors were higher in the post test. Data from Table 3 indicate that the mean values of student responses increased in items 4.5, 4.7, 4.9, 4.12, 4.13, 4.14, 4.16, 4.20, 4.23 and 4.27 for the posttest compared to the pretest. Most of these items were categorised under two factors which were enjoyment of performing practical and handling equipment and chemicals and also consideration of labwork as a way of learning. These findings are supported by the increased mean values in factor 2 and 4 for pre and posttest (Table 4). This indicates that after being exposed to the microscale experiments, students felt that they preferred doing experiments themselves compared to watching teacher demonstrations and reading the chemistry book. They also perceived that they can learn more by doing experiments, enjoy handling equipment and chemicals and can also understand basic concepts better when performing experiments individually. They also suggested that more time should be devoted to practical work and perceived that chemistry practical work is relevant in daily life. The lack of significance for each factor may be due to the small sample size of this study compared to findings by Vermaak (1997) whose sample size was larger. She had found that there was a significant difference for factors 1 and 3 at level 0.05 and factors 2 and 4 at level 0.01.
Table 4  
Mean Factor Values for the Attitude Inventory

<table>
<thead>
<tr>
<th>Factor</th>
<th>Mean Rating</th>
<th>t-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(Standard Deviation)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pre test</td>
<td>Post test</td>
</tr>
<tr>
<td>1</td>
<td>4.07</td>
<td>3.99</td>
</tr>
<tr>
<td></td>
<td>(0.57)</td>
<td>(0.54)</td>
</tr>
<tr>
<td>2</td>
<td>4.02</td>
<td>4.06</td>
</tr>
<tr>
<td></td>
<td>(0.44)</td>
<td>(0.49)</td>
</tr>
<tr>
<td>3</td>
<td>3.90</td>
<td>3.87</td>
</tr>
<tr>
<td></td>
<td>(0.42)</td>
<td>(0.44)</td>
</tr>
<tr>
<td>4</td>
<td>3.61</td>
<td>3.77</td>
</tr>
<tr>
<td></td>
<td>(0.55)</td>
<td>(0.57)</td>
</tr>
<tr>
<td>5</td>
<td>3.66</td>
<td>3.59</td>
</tr>
<tr>
<td></td>
<td>(0.73)</td>
<td>(0.59)</td>
</tr>
</tbody>
</table>

Level of Significance: 0.05

Note: The values of the mean ratings are calculated by reversing the scoring mode of the negative statements.

Data from Table 4 also indicates that the values of the mean ratings for all the factors during the pre and post tests ranged between 3.59 to 4.07. The most significant is the fact that the means of all the factors in the pre and posttest showed a trend close to ‘4’. This indicates that for the pre and posttest, the students’ attitude towards chemistry practical work are quite positive. Okebukola (1986) who used the Attitudes toward Chemistry Laboratory Work Scale developed and validated by Hofstein, Ben-Zvi & Samuel (1976) reported that a greater degree of participation in the science laboratory resulted in an improved attitude towards chemistry learning in general and towards learning in chemistry laboratory in particular.

Student responses to the scaled-responses motivation survey
which were categorised into six scales were analyzed and are shown in Table 5. The data from the pre and post tests for intrinsic goal orientation indicate that students were in a moderate level in this category with mean values ranging from 3.56 to 4.08. However, there were no significant differences for all items in this scale between pre and post tests. This indicated that the microscale approach did not change students’ preferences for challenging materials and assignments in order to learn new things, increase their curiosity and concentration in a subject. In contrast, the extrinsic goal orientation among the students was good since the responses ranged from 4.24 to 4.61. The data also indicated that the microscale approach did not affect their wants to improve their examination results since there were no significant differences between pre and post tests.

Table 5

<table>
<thead>
<tr>
<th>Item</th>
<th>Intrinsic goal orientation</th>
<th>Mean</th>
<th>Pre test</th>
<th>Post test</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1</td>
<td>In this subject, I prefer materials that are quite challenging, so that I can learn new things.</td>
<td>3.81</td>
<td>3.69</td>
<td></td>
</tr>
<tr>
<td>2.7</td>
<td>In this subject, I prefer materials which increase my curiosity although they are more difficult to learn.</td>
<td>4.08</td>
<td>3.98</td>
<td></td>
</tr>
<tr>
<td>2.13</td>
<td>Getting the maximum concentration in this subject maybe the highest satisfaction for me.</td>
<td>3.74</td>
<td>3.77</td>
<td></td>
</tr>
<tr>
<td>2.19</td>
<td>Whenever I’ve the chance in this class, I will choose the assignment that I can learn something although I cannot get a good result.</td>
<td>3.56</td>
<td>3.58</td>
<td></td>
</tr>
</tbody>
</table>
### Extrinsic goal orientation scale

<table>
<thead>
<tr>
<th></th>
<th>Description</th>
<th>Value 1</th>
<th>Value 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.2</td>
<td>To score a good result in this subject is my satisfaction.</td>
<td>4.33</td>
<td>4.31</td>
</tr>
<tr>
<td>2.8</td>
<td>For me, the most important thing is to improve my examination results, so the most important in this subject is to get good results.</td>
<td>4.36</td>
<td>4.24</td>
</tr>
<tr>
<td>2.14</td>
<td>If possible, I want to get better results compared to other students in this subject.</td>
<td>4.61</td>
<td>4.46</td>
</tr>
<tr>
<td>2.20</td>
<td>I want to be successful in this subject because it is important for me to prove my ability to the family and friends.</td>
<td>4.48</td>
<td>4.45</td>
</tr>
</tbody>
</table>

### Task Value Scale

<table>
<thead>
<tr>
<th></th>
<th>Description</th>
<th>Value 1</th>
<th>Value 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.3</td>
<td>I feel that I can use what I get in this subject for other subjects.</td>
<td>3.40</td>
<td>3.46</td>
</tr>
<tr>
<td>2.9</td>
<td>It is important for me to learn the material in this subject.</td>
<td>4.13</td>
<td>4.14</td>
</tr>
<tr>
<td>2.15</td>
<td>I’m very interested in the syllabus for this subject.</td>
<td>3.48</td>
<td>3.49</td>
</tr>
<tr>
<td>2.21</td>
<td>I think the course materials in this subject are beneficial for me to learn.</td>
<td>4.22</td>
<td>4.18</td>
</tr>
<tr>
<td>2.24</td>
<td>I like the content of this subject.</td>
<td>3.58</td>
<td>3.56</td>
</tr>
<tr>
<td>2.27</td>
<td>Understanding the content of the subject is very important for me.</td>
<td>4.14</td>
<td>4.08</td>
</tr>
</tbody>
</table>

### Control Belief of Learning Scale

<table>
<thead>
<tr>
<th></th>
<th>Description</th>
<th>Value 1</th>
<th>Value 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.4</td>
<td>If I learn in a proper way, I will succeed in learning this subject.</td>
<td>4.34</td>
<td>4.33</td>
</tr>
<tr>
<td>2.10</td>
<td>It would definitely be my own fault if I do not learn the material in this subject.</td>
<td>4.08</td>
<td>4.04</td>
</tr>
<tr>
<td>2.16</td>
<td>If I try my best, I can understand the concept and experiment in this subject.</td>
<td>4.37</td>
<td>4.24</td>
</tr>
<tr>
<td></td>
<td>Description</td>
<td>Rating 1</td>
<td>Rating 5</td>
</tr>
<tr>
<td>---</td>
<td>-----------------------------------------------------------------------------------------------</td>
<td>----------</td>
<td>----------</td>
</tr>
<tr>
<td>2.22</td>
<td>If I cannot understand this subject, it is because I do not try my best.</td>
<td>4.05</td>
<td>4.10</td>
</tr>
<tr>
<td><strong>Self-Efficacy for Learning and Performance</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.5</td>
<td>I am confident to get excellent results in this subject.</td>
<td>3.53</td>
<td>3.36</td>
</tr>
<tr>
<td>2.11</td>
<td>I’m confident that I can understand the difficult topics in this subject.</td>
<td>3.28</td>
<td>3.17</td>
</tr>
<tr>
<td>2.17</td>
<td>I’m confident I can understand basic concepts in this subject.</td>
<td>3.77</td>
<td>3.57</td>
</tr>
<tr>
<td>2.25</td>
<td>I’m confident to produce an excellent results in my assignment and tests related to this subject.</td>
<td>3.50</td>
<td>3.35</td>
</tr>
<tr>
<td>2.28</td>
<td>My target is to succeed in this subject.</td>
<td>3.59</td>
<td>3.37</td>
</tr>
<tr>
<td>2.30</td>
<td>I’m confident I can acquire the skills taught in this subject.</td>
<td>4.46</td>
<td>4.52</td>
</tr>
<tr>
<td>2.31</td>
<td>After considering my performance and the teacher for this subject, I think can succeed in this subject.</td>
<td>3.65</td>
<td>3.58</td>
</tr>
<tr>
<td><strong>Test Anxiety</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.6</td>
<td>Whenever we have a test, I think I’m very weak compared to other students.*</td>
<td>3.18</td>
<td>3.72</td>
</tr>
<tr>
<td>2.12</td>
<td>Whenever I take a test, I think about the questions in the other concepts sections that I cannot answer.*</td>
<td>3.56</td>
<td>3.53</td>
</tr>
<tr>
<td>2.18</td>
<td>Whenever I am taking the examination, I always think of the bad effects if I fail.*</td>
<td>3.94</td>
<td>4.14</td>
</tr>
<tr>
<td>2.23</td>
<td>I do feel uncomfortable and unsure whenever I take my examinations.*</td>
<td>3.21</td>
<td>3.47</td>
</tr>
<tr>
<td>2.26</td>
<td>I feel my heart racing whenever I take examination.*</td>
<td>3.47</td>
<td>3.37</td>
</tr>
</tbody>
</table>

*Statements formulated negatively
Rating was on a scale of 1 (Strongly disagree) to 5 (Strongly agree)
For the task value scale, students’ responses ranged between 3.40 to 3.58 in the pre and posttest for their interest in the syllabus, content of the subject and its usage for other subjects. For the items on importance in learning materials, benefits of course material and understanding content of subject, the responses were quite good since the responses are close to ‘4’. Data indicated that students’ responses for all items in control belief of learning ranged from 4.04 to 4.37. The mean values were quite similar for all items in the pre and post tests except for their understanding of the concepts and experiments in this subject.

For self-efficacy for learning and performance scale, the students’ responses ranged between 3.17 to 3.77 for all items in the pre and post tests except for their confidence in acquiring the skills taught in this subject which was 4.46 and 4.52 in the pre and posttest respectively. Data showed that mean values for most items decreased in the posttest but the differences were not significant. This indicated that the microscale approach did not change students’ self-efficacy in learning and performance. Yoo, Hong & Yoon (2006) had also conducted research on the effect of a small scale chemistry programme on academic self-efficacy of Korean High School students. Comparison of the 4 categories in academic self-efficacy such as self-confidence, self-regulation, task difficulty preference and self-efficacy on science were carried out. Her results showed that the self-confidence score of the small scale chemistry group is significantly higher than the comparison group. Data for the test anxiety in Table 5 shows that responses for all items ranged between 3.18 to 4.14. Overall, this indicates that level of anxiety among the students involved in this study was quite high. There were no significant differences for most of the items in this scale between pre and post test mean values which show that the microscale approach did not affect anxiety among the students. Although the microscale technique permitted the students to do experiments
individually, there were still students who were not very confident to conduct them due to their lack of skills. In contrast, Yoo et al. (2006) found that through their small scale lab programme, students’ anxiety towards science were decreased. However, her findings were limited to the number and level of difficulty of experiments carried out in her study.

There were no significant differences among the motivation scales between the pre and posttest (Table 6). On the posttest, the mean value for most of the items decreased whereas only a few increased and for every item, only small differences occurred (Table 5). Despite these small differences on individual items, the overall results for the pre test and post test showed no significant differences. Overall, this indicates that the microscale experiments did not affect students’ motivation in their learning. In contrast, Madeira (2005) found that the interest and motivation of the students from Mozambican Junior Secondary Schools increased after using microchemistry kits. This significant difference in their interest and motivation may be because their students have been exposed to less practical work in chemistry before the treatment whereas in the Malaysian context, the students have been used to traditional laboratory work in the lower secondary levels.
Table 6
Mean Factor Values for All the Motivation Inventory

<table>
<thead>
<tr>
<th>Scale</th>
<th>Mean Rating (Standard Deviation)</th>
<th>Pre test</th>
<th>Post test</th>
<th>t-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N = 75</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intrinsic goal orientation</td>
<td>3.80 (0.49)</td>
<td>3.76 (0.50)</td>
<td>0.66</td>
<td></td>
</tr>
<tr>
<td>Extrinsic goal orientation</td>
<td>4.45 (0.44)</td>
<td>4.37 (0.49)</td>
<td>1.56</td>
<td></td>
</tr>
<tr>
<td>Task Value</td>
<td>3.83 (0.47)</td>
<td>3.82 (0.45)</td>
<td>0.13</td>
<td></td>
</tr>
<tr>
<td>Control Belief of Learning</td>
<td>4.21 (0.57)</td>
<td>4.18 (0.53)</td>
<td>0.55</td>
<td></td>
</tr>
<tr>
<td>Self-Efficacy for Learning and Performance</td>
<td>3.54 (0.46)</td>
<td>3.42 (0.48)</td>
<td>3.01</td>
<td></td>
</tr>
<tr>
<td>Test Anxiety</td>
<td>2.41 (0.58)</td>
<td>2.35 (0.56)</td>
<td>0.94</td>
<td></td>
</tr>
</tbody>
</table>

Level of significance: 0.05
Note: The values of the mean ratings are calculated by reversing the scoring mode of the negative statements.

Berg (2005) reported that no research focused solely on motivation has been conducted and his studies had shown a relationship between motivation and attitude. His findings indicated that a positive attitude change towards learning chemistry was associated with evidence of motivated behaviour, while a negative change was linked to less motivated behaviour. Findings from this study indicate that there were no significant attitude and motivation changes as a result of performing microscale experiments.

Student perceptions towards the microscale chemistry experiments are presented in Table 7. The mean values for items 5.2, 5.5, 5.6 and 5.7 ranged from 3.82 to 4.38. The values showed a
trend close to four and above. This indicate that students agreed that by doing the experiments individually, they can understand the experiments and concepts better. They were also keen to do more experiments and perceived that microscale experiments were fun and could be done quickly. These findings are also supported by many researchers who found that conducting experiments with microscale techniques promoted time savings (McGuire, Ealy & Pickering, 1991, Bradley, 1999, Singh, Szafran & Pike, 1999, Kelkar & Dhavale, 2000, Vermaak & Bradley, 2003, Tallmadge, Homan, Ruth & Bilek, 2004).

Table 7  
Students’ Perceptions Towards Microscale Chemistry Experimentation

<table>
<thead>
<tr>
<th>Number Of item</th>
<th>Perception towards microscale chemistry experiments</th>
<th>Percentage of responses (%)</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.1</td>
<td>It is difficult to handle the microscale equipment.</td>
<td>84.5 10.4 5.2 1.81</td>
<td></td>
</tr>
<tr>
<td>5.2</td>
<td>Doing the experiment myself makes me understand the experiment and concepts better.</td>
<td>7.7 16.7 75.6 3.95</td>
<td></td>
</tr>
<tr>
<td>5.3</td>
<td>The results of a microscale experiments are not observed easily.</td>
<td>57.2 31.2 11.7 2.40</td>
<td></td>
</tr>
<tr>
<td>5.4</td>
<td>I was afraid to try out these microscale experiments.</td>
<td>91.0 7.7 1.3 1.59</td>
<td></td>
</tr>
</tbody>
</table>
5.5 The experiments could be done quickly.  
5.6 It is fun to do the microscale experiments.  
5.7 I am keen to do more microscale experiments.  
5.8 Microscale experiments are not real experiments.  
5.9 Microscale chemistry equipment is a cheap version: we should use the real equipment. 

The mean values for items 5.1, 5.3, 5.4, 5.8 and 5.9 range from 1.59 to 2.47. This indicated that students did not agree that the microscale equipment was difficult to handle, results of the experiments were not observed easily and that they were afraid to try out the experiment. They also did not agree that the microscale experiments were not real.

The students perceived that microscale experiments were easy to handle and they were very keen to do more experiments. They also understood the experiments and concepts better by doing experiments individually. These findings are supported by Vermaak (1997) who reported high positive mean values for the African pupils’ perceptions of handling and managing the microscale experiments. They felt that microscale experiments were beneficial, fun to do and made them enjoy practical work. In contrast, McGuire et al. (1991) found a persistent preference for macro experiments over microscale experiments. However, his findings were limited to the number of experiments and students involved in his study.
Analyses of Open Comments

The comments from the students indicate that most of them had a positive view towards chemistry laboratory work. They perceived that practical work is fun, can create interest, help them get more knowledge and will help them to understand chemistry concepts better. These findings are supported by Wilkinson & Ward (1997) who found that most students agreed with their teacher that laboratory work helps them understand theory work better. They also suggested conducting more chemistry practicals and increasing the quantity of equipment in the laboratory. The negative views included having difficulties in doing experiments in a group and failing to finish lengthy experiments.

Most of the students also perceived that microscale chemistry experiments were fun and easy to handle because the apparatus was small, not easily broken, safe and could be easily brought anywhere. By doing microscale experiments, students can learn new skills, increase understanding of concepts and stimulate their interest to do experiments and learn chemistry. They also enjoyed doing microscale experiments because everyone has a chance to do so. Compared to traditional experiments, observations can be made clearly and quickly. Microscale experiments are also suitable for schools since the apparatus can be easily obtained, experiments pose less danger and are easier to do compared to traditional experiments. This approach can also encourage the students to do experiments carefully and patiently. Kelkar & Dhavale (2000) also reported that undergraduate students performed experiments with more care and their skills in handling the equipment were markedly improved after adoption of this new technique in their laboratory.

Students also suggested doing more microscale experiments because it will help them in understanding chemistry concepts. On the other hand, some thought that the microscale experiments were quite difficult to handle and the small equipment could be
easily lost. Vermaak (1997) reported that the majority of African students in her study were in favour of this approach with positive responses similar to Malaysian students. These findings are also supported by Madeira (2005) who obtained similar responses from Mozambican students and teachers. Yoo, Hong & Yoon (2006) also found that Korean High School students perceived that small-scale chemistry experiments were convenient, marvelous and interesting and also suitable for doing experiments individually or in a group.

Conclusions

Even though the microscale chemistry experiments did not improve student attitudes and motivation towards chemistry practical work, students did develop a positive view of practical work and microscale chemistry experimentation. The mean values for all the items for pre and posttest indicated that the students preferred doing experiments instead of watching teacher demonstrations. They enjoyed handling equipment and chemicals and also understood basic concepts better when they performed experiments individually. They also suggested that more time should be devoted to practical work and perceived that chemistry was relevant to daily life. The majority of the students were very supportive of microscale chemistry experiments. Their positive comments on microscale chemistry experiments include those that mentioned the experiments were fun to do, could be done quickly, were easy to handle, could stimulate their interest in doing experiments and increase their understanding of chemistry concepts.

Acknowledgements

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References


