THE EFFECTS OF INDUCTİVE TEACHİNG METHODS İN AN ELECTROCHEMİSTRY CLASS

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Abstract

Reasoning is a skill used in making logical, just and rational judgements. Mastering of critical and creative thinking skills and thinking strategies is made simpler if an individual is able to reason in an inductive and deductive manner. Making generalisations or inductive reasoning is one of critical thinking skills that are listed in the Malaysian secondary school chemistry syllabus. This study intends to investigate chemistry teachers' knowledge and skills of the inductive teaching methods, and to seek the effects of the inductive methods on students' performance in solving electrochemistry problems. Subjects were 5 chemistry teachers and 66 students of a school in the state of Perak in Malaysia. To address the first research question, this study employed the quasi-experimental methods. The treated group was taught on the topic of electrolysis of aqueous solutions by the researcher. She employed the inductive teaching methods derived from a module constructed by the expert chemistry teachers in Selangor. The controlled group was taught by the researcher engaging the traditional lecture method. This study employs the interviewing methods to address the second, third, and fourth research questions. A set of structured and semi structured written interview questions, a verbal interview and a think-aloud interview were constructed to address the qualitative aspects of the research questions. The mean difference of 7.017 showed that the inductive group performed better than the traditional group in the post test. Findings from the interviews revealed that chemistry teachers did not seem to have the adequate knowledge and skills on the inductive teaching methods and weak students could solve the electrochemistry problems when guided and prompted the inductive way.

Keywords: *Inductive teaching methods, chemistry teaching, teaching electrochemistry*

Introduction

Chemistry is a science that studies the properties, composition and structure of chemical substances and the changes they undergo (Loh & Tan, 2006). It is a field of study that involves physical phenomena and students are continuously required to identify 'hidden' concepts, define adequate quantities and apply underlying laws and theories using high-level reasoning skills (Nurrenbern & Pickering, 1987, Nakhleh, 1993). Reasoning is a skill used in making logical, just and rational judgements. Mastering of critical and creative thinking skills and thinking strategies is made simpler if an individual is able to reason in an inductive and deductive manner. Making Generalisations or inductive reasoning is one of critical thinking skills that are listed in the Malaysian secondary school chemistry syllabus (Curriculum Specifications, CDC, 2004).

Elements in the periodic table are divided into several groups which have similar properties and electronic configurations etc. Thus if the properties of individual elements in a group like chemical reactivity, melting point, boiling point, ionization energy etc. are known, the properties of the elements of the entire group can be predicted with very few exceptions. Thus it proceeds from specific to general and thus this is an example of inductive method. Inductive teaching methods are teaching methods that facilitate students to employ specific data to arrive at a general conclusion (Joyce & Weil, 2000). Pupils make a number of observations which are then sorted into a concept or generalization; the individual does not have prior knowledge of the abstraction but only arrives at it after observing and analyzing the observations. It is the opposite of deductive methods. However, like deduction, the process of induction is a very common and often unconscious process in humans. In this approach, teachers would present pupils with data, ask them to make observations, on the basis of these observations, form the abstraction being taught.

It has been established that students learn more effectively in active and cooperative learning environments in which they may develop new ideas logically from simple principles by a process which involves inductive reasoning (Bransford, Brown & Cocking, 1999). "Increasing students' engagement in the classroom is becoming an essential element to reaching students who are often equipped with ever increasing technological distractions and whose attention span seems to be ever decreasing." "However,...incorporating activities that were easy or fun to do did not necessarily mean students were developing a conceptual understanding or higher order thinking skill" (Bonwell & Ellison, 1991 as cited in Hutchinson, 2000, p 3).

In Malaysians schools particularly, chemistry is traditionally taught deductively. The instructor introduces a topic by lecturing on general principles, then uses the principles to derive mathematical models, shows illustrative applications of the models, gives students practice in similar derivations and applications in homework, and finally tests their ability to do the same sorts of things on exams. Hence, the purpose of this study is to investigate chemistry teachers' practice of the inductive teaching methods and to seek the effect of the inductive methods on students' performance in solving electrochemistry problems. Specifically, the study focuses on the following research questions:

(i) Do the inductive teaching methods have a positive impact on students' performance in solving electrochemistry problems?
(ii) What are the perceptions of chemistry teachers' on the inductive teaching methods?
(iii) How do chemistry teachers' perceive on how they carry out the inductive teaching methods in their chemistry classroom?
(iv) Can chemistry students' solve electrochemistry problems when guided by the inductive prompting methods?

Literature review

Problems in learning Electrochemistry

Schmidt, Marohn & Harrison (2007) joined in a study to identify and understand secondary-school students' problems in learning electrochemistry at an introductory chemistry level. The investigation covered four areas: (a) electrolytes, (b) transport of electric charges in electrolyte solutions, (c) the anode and the cathode, and (d) the minus and plus poles. Written tests were given to high-school students in five cycles. The population from which random samples were drawn totalled 15,700 subjects. Students were asked to select the correct answers and to justify their choices. It was found that students based their reasoning on four alternative concepts: (a) During electrolysis, the electric current produces ions; (b) electrons migrate through the solution from one electrode to the other; (c) the cathode is always the minus pole, the anode the plus pole; and (d) the plus and minus poles carries charges. The results suggested a teaching strategy in which students should first experience and learn about electrochemistry concepts. In the second step, appropriate concept terms would be added, and students would then be confronted with alternative concepts **(**Schmidt, Marohn & Harrison, 2007).

Onno, Acampo & Verdonik, (2006) carried out a case study of problems which can occur when teaching the topic of redox reactions to Grade 11 students. Two chemistry teachers, a senior and a junior teacher, were involved in the study. Their reflective comments on the teaching problems were also investigated. Research data were obtained from classroom observations and audio tape recordings of classroom practice. After the lessons, they conducted semi structured interviews with the teachers. The teaching problems were reported in terms of teaching activities that caused difficulties for students in considering new conceptions.

Niaz & Chacón (2003) designed a teaching strategy based on two *teaching experiments* that could facilitate students' conceptual understanding of electrochemistry. The study was based on two sections (control, n D 29; experimental, n D 28) of 10^{th} grade high school students at a public school in Venezuela. Experimental group participated in two teaching experiments designed to generate situations/experiences in which students are forced to grapple with alternative responses leading to cognitive conflicts/contradictions. Results obtained show that learning electrochemistry involves both algorithmic and conceptual problems.

Problem Solving In Chemistry

Problem solving skills are specifically important in chemistry (Bunce, Gabel & Samuel (1991). Many researchers agreed that problem solving is one of the most important goals and a desired outcome of learning chemistry (Gabel and Bunce, 1994; BouJoude and Barakat, 2003). Reid and Yang (2000) (also cited in BouJoude and Barakat, 2003) states that inappropriate chemical knowledge prevents students' problem solving ability in chemistry and students becomes unsuccessful if chemistry instruction does not provide them with an adequate set of rules to follow or do not help them to understand chemical knowledge during the learning process. Hence, it is essential to help students to understand the pre-requisite knowledge and skills of problem solving and prevent them from simply applying memorized skills in rote fashion.

Problem solving skills could be promoted by providing environment rich in potential for exploration and by encouraging students to reflect on their actions (Smith, 1991). Smith (1991) proposed the efficient problem solving process as four stages: understanding the problem, devising a plan, carrying out the plan and looking back. Duncan and Johnstone (1979) also posited that it seemed necessary to develop new learning environments incorporating the instructional strategies to enhance the learning of abstract chemical concepts in order to develop learner's problem solving skills.

Teachers are not properly trained to teach problem solving (Powers, 1984). When teachers discuss problem solving with pupils, they assume pupils will become involved with the thinking operations of analysis, synthesis and evaluation (higher-level thinking skills) (Blosser, 1988). Rajendran (2004) also reported 61.8% teachers thought that they had not been exposed sufficiently on how to teach thinking skills. In addition, problem solving strategies involves formal operational skills such as proportional reasoning and inductive-deductive thinking. Some research reports that fifty percent of college chemistry students are not competent formal operational thinkers (Helgeson, 1985). Thus, it seems logical to conclude that most high school students may not also reach this level of thinking.

Research (Schmidt, 1992) reports that when solving chemistry problems many students tend to use algorithmic methods. This is especially true for students who have not sufficiently grasped the 'chemistry' behind the problem. When solving chemistry problems, they may use a memorized formula, manipulate the formula and plug in numbers until they fit (Gabel & Bunce, 1994). Schmidt (1992) put forward the hypothesis that the problem solving strategy a student might apply depends on the difficulty of the problem. A difficult problem is preferably solved using algorithms students have learned. If a problem is easy, the person is more inclined to use a strategy based on reasoning.

In another study, BouJaoude and Barakat (2003) examined the relationship between students' conceptual understanding and their performance in stoichiometric problem solving. They reported that students with more conceptual understanding could use the algorithmic approach correctly more than those with less conceptual understanding. Their study also showed that in the interviews, students with more conceptual understanding were generally more able to argue conceptually than those with less conceptual understanding.

One research showed that form four students do faced problems when learning electrochemistry. Among the problem faced are weak comprehensions of basic concepts, writing balance equation and describing an electrolysis process. It is suggested that teachers should plan and implement suitable teaching and learning strategies based on constructivism to help students in the learning process of learning electrochemistry (Tay Chien Wei, 2008).

Inductive Teaching Methods

The inductive method is deeply entrenched in Science education. Traditionally science courses were taught deductively, with the teacher teaching the students the facts and theory, then moving to textbook exercises and finally application. Using the inductive method, the teacher presents the students with a specific challenge or problem, such as an experiment that needs to be interpreted, or a real-world problem that needs to be solved. The students must then use their base-knowledge to investigate, test, analyze and come to their own conclusion or solution. The inductive method, which is commonly interpreted in schools as the scientific method is widely used as a guide for observation, inquiry based learning and serves as a guideline for student investigation into science. In science classrooms, students are often guided through the process of induction by the following steps:

1. State the Question: What information do you wish to obtain?
2. Make Observations: Gather information that will help answer your questions by researching, making, and recording direct observations of the subject.
3. Form a Hypothesis: After gathering an adequate amount of information, apply what you have observed to form an educated guess or prediction of what the answer to your question is.
4. Test: Test your hypothesis by performing an experiment that includes a variable.
5. Analyze: Examine the results of your experiment to understand what they imply.
6. Draw a Conclusion: Based on the interpretation of your results, develop a general principle as an answer to your question. (Prince & Felder, 2006)

Scientists create scientific laws by observing a number of phenomena, finding similarities and deriving a law which explains all things. A good scientific law is highly generalized and may be applied in many situations to explain other phenomena. For example, the laws of gravity were used to predict the movement of the planets. Of course when you find a law, you have to spend ages proving it and convincing others that it is true. Inductive arguments are always open to question as, by definition, the conclusion is a bigger bag than the evidence on which it is based.
'When students engage in the construction of knowledge, an element of uncertainty are introduced into the instructional process and the outcomes are not always predictable; in other words, the teacher may not be certain what students will produce. In helping students become producers of knowledge, teachers' main instructional task is to create activities or environments that allow them to engage in higher order thinking.'
(Department of Education, Queensland. A guide to productive pedagogies: Classroom reflective manual, 2002, p 1)

The inductive teaching method or process goes from the specific to the general and may be based on specific experiments or experimental learning exercises. Deductive teaching method progresses from general concept to the specific use or application. The most significant difference between these forms of reasoning is that in the deductive case the truth of the premises (conditions) guarantees the truth of the conclusion, whereas in the inductive case, the truth of the premises lends support to the conclusion without giving absolute assurance. Inductive arguments intend to support their conclusions only to some degree; the premises do not necessitate the conclusion.

Several of the most commonly used inductive teaching methods are inquiry learning, problem-based learning, project-based learning, case-based teaching, discovery learning, and just-in-time teaching (Prince & Felder, 2006). These methods have many features in common, besides the fact that they all qualify as inductive. They are all *learner-centered* (aka *student-centered*), meaning that they impose more responsibility on students for their own learning than the traditional lecture-based deductive approach does.

One study in an economy class done by Jong, Acampo and Verdonk (1995) reported that inductive teaching increases students' performance and that learning is enhanced if inductive teaching is done prior to presenting general theories. They also concluded that learning is enhanced if teachers use methods that cause students to experience economic concepts before they begin to lecture over the general theory associated with that concept.

Neubert & Binko (1991) also posited the inductive approach to learning helped ensure an interactive environment where students use their languages processes to learn. They suggested teacher training should include direct experience with the inductive approach, analysis of the experiences and coaching in field settings. Three studies involving 174 elementary schools carried out by Klauer (1996) found the results supported the hypothesis that training in an inductive strategy would enhance problem solving.

One interesting paper was presented at the Annual Meeting of the Northern Rocky Mountain Educational Research Association (1984) by Joanne Kurfiss. She reported teachers had four general difficulties in implementing inductive teaching methods. While teachers appeared to grasp and use the basic learning cycle lesson planning methods for inductive teaching, the examinations showed the following difficulties: (1) failure to clarify lesson objectives; (2) over-emphasis on activities; (3) blurring conceptually distinct phases of the learning cycle, or omitting a phase; and (4) inadequate planning for evaluation, particularly of high level cognitive or affective outcomes of a lesson.

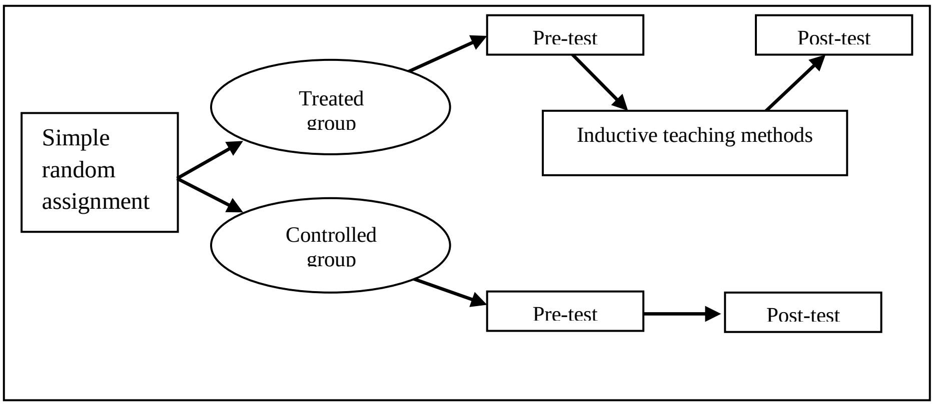
Barrish (1970) studied the relationship between levels of divergent thinking and the differential effectiveness of inductive and deductive teaching strategies. He found for the learning of low cognitive mathematical material, the deductive-reception strategy proved superior to the inductive-guided discovery strategy. The findings from this study seemed to contradict a study done by Silverstein & Osei-Prempeh (2010). They implemented a combination of inductive and deductive laboratory exercises in senior-level process control course for the engineering students. While students indicated an overall preference for deductive laboratory exercises, the subjective instructor assessment showed improved learning from the inductive exercises.

One study conducted by Schelfhout, Dochy, Janssens, Struyven, Gielen & Sierens (2006) investigated the possible approaches within teacher training which could encourage student teachers towards learning-focused teaching activities. The main question is whether students from teaching institutions were taught in a more inductive way pays more attention to these aspects during teaching practice. Comparisons of the institutional approaches with the approaches during teaching practice confirm the importance of an inductive approach in which different practice experiences, systematically aimed at making the students restructure their conceptual frameworks of learning and instruction, are used for reflection.

Methods

The study employed a mixed method design. It engaged both quantitative and qualitative approaches. In this study, the mixed method design is engaged because the researcher wished to follow up a quantitative study with a qualitative one to obtain more detailed and specific information than the findings gained from the results of statistical tests. To address the first research question, this study employed the quasi-experimental methods. Simple random assignment selection method was chosen to divide the respondents into the controlled and treated groups (Kahn & Best, 2006). The respondents were not randomly selected since all available students from both classes were roped into the study.

As a measure to get balanced groups, the researcher decided to combine the name list of both classes and arranged the names according to their mid-term scores. Those with extreme marks (highest and lowest) were set aside first. Then the name list was arranged so that the female and male names were alternated. Based on this list, the researcher then carried out the simple random assignment method to divide the group into controlled and treated groups.



The pre and post test controlled group method is an effective design to minimise internal threats onto experimental validity. According to Gay, Mills & Airasian (2009), if researcher used short study duration and both controlled and treated groups were considered have no prior knowledge towards the dependent variable, the pre and post-test controlled group can be employed. The treated group was taught on the topic of electrolysis of aqueous solutions by the researcher. She employed the inductive teaching methods derived from a module constructed by the expert chemistry teachers in Selangor (Wan Afifah, 2002). The controlled group was taught by the researcher engaging the traditional lecture method. The topic took four periods to finish (two weeks).

This study employs the interviewing methods to address the second, third, and fourth research questions. Interviewing is a way for a researcher to check the accuracy of; to verify or refute, the impressions or information he or she has gained from another source. Researchers interview people to find out those things that cannot be observed such as feelings, thoughts, understandings and intentions (Fraenkel & Wallen, 2003). This study hoped to probe teachers' understanding and practice on the inductive teaching methods and to determine respondents' thinking process when solving the electrochemistry problems.

A set of written interview questions, a verbal interview and a think-aloud interview were constructed to address the qualitative aspects of the research questions. These structured and semi-structured interviews were designed to elicit specific answers from the respondents. The written interview was constructed to gauge teachers' understanding on inductive teaching methods and the verbal interview was constructed to determine teachers' implementation of the teaching methods in chemistry classes. The think-aloud interview however, was designed to investigate if the inductive way of prompting would help students' solving the electrochemistry problems.

The population of the study comprised two classes of Form Four science students of a secondary school in the state of Perak, Malaysia. The school had two pure science classes with a total of 66 students. The classes were streamed based on the grade of PMR results. Form Four students were selected as respondents because the topic of electrochemistry was taught in the second semester of that academic year. Form Four students were also selected because they were not yet required to sit for the national SPM examination. This means easier access to the students and less disruptions to the school schedules and time-table. Gender ratio of the population is almost 1 to 1 with the actual ratio of female to male being 39:27 or 1.4:1. This serves as an advantage to the research as it can reduce the 'gender effect' on the results. Since the researcher also taught both classes herself, it is also hoped to eliminate the 'teacher effect' on the results.

To address the qualitative part of the study, this research employed a written interview, verbal interview and a think-aloud interview methods. Ten students were randomly selected from the 66 students as respondents for the written subjective questions and think-aloud interview. These ten students were selected by randomly selecting five students from each of the two groups. All five chemistry teachers from the school were interviewed for their perceptions on inductive teaching methods.

In short, instruments employed in this study were as follows:

- (i) a written test to estimate the students' performance in solving electrochemistry problems
- (ii) written interview questions to glean teachers' understanding on inductive teaching methods
- (iii) oral interview questions to determine teachers' implementation of the teaching methods in chemistry classes
- (iv) think-aloud interview questions to probe students' conceptual understanding of the electrochemistry problems

Prior to constructing the test, an in-depth study on the topic of electrochemistry was done according to the KBSM curriculum. The author set up the test preparation table to approximate the content validity of the instruments. The items were revalidated by two expert teachers in state of Selangor, Malaysia. This was to ensure that the test did not include what Malaysian secondary school students do not learn. Pilot tests were conducted twice to eliminate confusing items and to ascertain the test could be carried out within the allocated time. The reliability of the written tests was estimated by engaging the tests of correlation coefficient of the Spearman or Candle rank ($r = 0.918$). This was done by appointing two distinguished examiners (experienced chemistry teachers) to score the pilot tests according to the marking scheme and then the researcher correlates between the two examiners.

To establish the content validity of the items of the interviews, the questions were scrutinised by experts from two local universities. The content validity of the electrochemistry problems were also validated by expert teachers of the subject matter. Feedback from the experts was crucial when modifications of the instruments were made. While the reliability of the quantitative instrument depends on instrument construction, reliability of qualitative instruments very much depend on the researcher herself (Patton, 2001). Qualitative research depends heavily on the ability and effort of the researcher. The reliability of the instruments was estimated by taking every possible precaution against biases and 'over interpretation' of data. For instance, in the written interview scripts, students were asked not to write their names on the paper. When interviewing the teachers, the researcher took the effort to make sure it was done formally, in a secluded area where the researcher and the interviewee would not be disturbed. In the think-aloud interview, one research assistant (a chemistry teacher) was also present and taking down notes during the interview. Thus, the researcher was able to confirm with the other teacher of what has been written in her notes and clarify things that were not very clear to the researcher. This method of triangulation has been adopted to control biases and establishing valid propositions or evaluation of the findings (Patton, 2001).

In order not to disrupt any of the school's schedules, the research had to be done outside official school hours. Two pilot studies were conducted prior to the test to identify problems that might arise from the instrument. The researcher then proceeds to teach the controlled group using the traditional lecture method and the treated group with the inductive teaching methods. After two weeks of teaching, respondents from both groups were asked to sit for the written test. Arrangement was made with the other chemistry teachers so that all respondents of the two classes could sit for the test simultaneously to reduce missing respondents. Students were already told the goals of the research and participation was voluntary. It was made clear that confidentiality of responses was respected (students were not required to write their names on their papers) and participation or lack of participation will not influence their grades in the final school examinations. The researcher was present during the test to enable respondents and researcher seeks clarification from each other to clear any doubts that may arise from them. This method of data collection is believed to be efficient with respect to time and expense.

The think-aloud interview were carried out right after the test. Ten randomly selected students from the two classes were requested to go to the chemistry laboratory after the subjective test to answer the questions. Again, here the researcher reminded all respondents, they were not required to tell their names, that participation is voluntary, and they were free to go if they did not wish to participate in the interview. None of them seemed anxious to go so the researcher proceeded with the interview. All of the ten students were interviewed by the author. The students were given one open-ended electrochemistry question to answer. During the problem solving exercise the respondents were requested to explain what they were doing. The researcher used the probing questions to encourage the students to say out whatever they were thinking, what went in their minds when they were solving the problems. Since the researcher hoped that the respondents would elaborate their answers, the interview was done in a relaxed atmosphere and the interviews were started with some general questions. Sometimes when the students seemed quiet or at a loss on what to do, they were prompted with some remarks or questions. Since some of them answered the question very briefly, the researcher also gently probed and encouraged the respondents to be more elaborate in their answers. Based on the predetermined probing questions, the interview was casually led to the research questions and the researcher just took notes discreetly and did not use any tape recorder to minimise any uncomfortable feelings that may arise from the unusually long conversation. Sometimes the researcher showed her notes to the interviewee to check whether she had heard and written the correct responses. After that the researcher carried out triangulation with the other chemistry teacher.

The verbal interview on the five teachers however, was carried out the following week. Three senior teachers and two young teachers were respondents of the interview. While setting the date for the interview, the researcher informally asked for their consent to participate in the study and informed them that the confidentiality of their responses would be respected. The teachers were then engaged in formal interviews after school hours. The researcher made some arrangements to have the interview in a secluded area where she, her assistant (another chemistry teacher) and the interviewee would not be disturbed. The author started with some 'warming up' questions, e.g. their teaching experience, their passion of teaching, family and educational background, current issues etc. The researcher was the sole interviewer but both she and the other chemistry teacher took down notes during the interview for the purpose of triangulation of data. To eliminate the probability of mistaken audio ability, sometimes the researcher showed her notes to the interviewee to check the transcriptions and to determine the accuracy of the responses recorded.

Results and Discussion

The independent samples t-test results showed the mean score of both groups (refer Table 4.1) Levene's test showed no significant difference, $t(64) = 3.524$ and $p>.05$, thus confirming the assumptions that variance of the post test scores were equal. The t-test also showed that there was no significant statistical difference between the mean scores of both traditional and inductive groups. Hence, both groups were equal in terms of prior knowledge and performance.

Table 4.1

Independent samples t-test (Pre-test)

	Levene's Test for Equality of Variances		t-test for Equality of Means						
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std Error Difference	95% Confidence Interval of the Difference	
								Lower	Upper
Equal variances assumed	0.003	0.96	**3.524**	64	0.79	4.242	1.204	1.837	6.648
Equal variances not assumed			3.524	64	0.79	4.242	1.204	1.837	6.648

To address the first research question, the scores of both traditional and inductive groups were analysed to test the following hypothesis:

Ho1: There is no significant difference in students' performance between the traditional and the inductive group.

Table 4.4 and 4.5 below showed the results:

Table 4.4

Group Descriptive Statistics

Group	Mean	N	Std. Deviation	Std. Error Mean
Traditional	15.27	33	3.581	2.08
Inductive	19.52	33	5.918	2.04

Table 4.5

Independent samples t-test (post-test)

	Levene's Test for Equality of Variances		t-test for Equality of Means						
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std Error Difference	95% Confidence Interval of the Difference	
								Lower	Upper
Equal variances assumed	0.004	0.947	2.445	64	**.012***	7.017	2.816	13.053	1.38

Equal variances not assumed	2.445	64	0.012	7.017	2.816	13.053	1.38

Table 4.4 and 4.5 showed the statistical significant difference in the post-test scores for both traditional and inductive groups, t(2.445) df = 64, p , .05) and for the traditional group with M = 15.27 and inductive group with M = 19.52. The mean difference of 7.017 showed that the inductive group performed better than the traditional group in the post test. Hence, the Ho(1) was successfully rejected.

The statistical analysis showed the treated group (inductive method) performed better than the controlled group (traditional lecture method) in the post-test. Students underwent the inductive teaching methods seemed to have significant higher scores (t (2.445) df = 64, $p < .05$) compared to the controlled group students. Hence, Ho1 that states there is no significant difference in students' performance between the traditional and the inductive group is successfully rejected. The results indicated students underwent the inductive teaching methods were able to solve problems on electrolysis of aqueous solutions better than the students from the controlled group. The findings seemed to indicate that the inductive teaching methods were able to enhance students' ability in solving problems of the electrolysis of an aqueous solution. This study supports Russell's study (1997) that four criterion needed to help students build firmer conceptual understanding are: (i) structure and guidelines to study; (ii) motivation; (iii) identification of difficult concepts; (iv) opportunities for students to identify and rectify the misconceptions; and (v) guided problem solving.

Analysis from the written interview:

All five teachers did not give the correct ideas of what actually constitutes as inductive teaching methods. Some responses revealed that teachers do not seem to have the appropriate knowledge of the inductive teaching methods. The teachers' answers to the first question seemed to camouflage the inadequacy of their knowledge of the inductive teaching methods. Most teachers tried to show that they really knew about the inductive teaching methods. These responses however, contradict with their answers to question 2.

All five teachers conceded that they had used the inductive teaching in their class. Teacher A and C might had claimed that they used the inductive teaching methods very often due to their inadequate knowledge of what really constitutes the inductive methods. The other three teachers that might have some ideas of what the inductive methods are, seemed more cautious in their responses. Teacher A used the topic of 'Chemicals for Consumers' in her answer. She illustrated that she would start by showing students some samples of food additives. Students then would need to classify them according to the functions. Teacher B gave the topic of 'mol' but did not explain further on how exactly the class would proceed. Teacher C gave the topic of 'Chemical Equations' but also failed to give clearer illustrations on how she would teach the topic. Teacher D did not answer question 4. Teacher E named the topic of 'Rate of Reactions' in her answer. She implied that students should be able to figure out that higher temperature would increase the rate of reactions, without clear illustrations on how this could be achieved in the class. Three teachers mentioned that it is difficult to use the inductive teaching methods due to time constraints (Teacher C, D and E). Both Teacher A and B just stated that it is easy to use the method but they failed to elaborate on the answers.

Surprisingly, despite their confident answers, all teachers conceded that they need to improve their knowledge and skills on the inductive teaching methods. Their answers seemed to confirm the author's suspicions that their knowledge and skills on the inductive teaching methods are not adequate. As expected, all the five teachers reported that they are willing to participate in a course or workshop on the inductive teaching methods.

The written interviews revealed the teachers' inadequate knowledge and skills of the inductive teaching methods. All teachers claimed that they had employed the inductive teaching methods in their chemistry classes. However, when explaining on how they implemented the methods in class, most teachers could not give satisfactory answer. Their inability to be specific in the written interview yielded shocking inadequacy of chemistry and science teachers' knowledge and skills of the inductive teaching methods. The inductive teaching methods are supposed to be implemented in a science class hand in hand with the deductive methods, complementary to each other in the effort of emphasising the inductive and deductive reasoning in children as one of the scientific thinking skills.

Analysis of the verbal interview

The verbal interviews were conducted in Bahasa Melayu (Malay) since all respondents were hesitant to talk in English. It could be discerned that most respondents were not really sure of what constitutes the inductive teaching methods. Some really had no idea at all and may never try it out in the classroom. Two of the teachers (Teacher D and E) seemed to have some idea on what the inductive teaching methods is all about, but did not seem to know exactly on how to implement it in class. The interviews revealed that some responses given in the written interview did not hold water. Teachers seemed to reluctant to reveal that they do not have adequate knowledge and skills on the inductive methods, however were quite willing to go for training if possible. This is at least encouraging. Nevertheless, it was quite shocking to find out that most science teachers that had gone through formal teaching training did not seem to have the adequate knowledge and skills on the inductive teaching methods.

The verbal interviews confirmed the author’s suspicions of teachers’ inadequacy knowledge and skills of the inductive teaching methods. Most teachers admitted of not knowing precisely what the inductive teaching methods mean. These findings seemed to support Rajendran’s (2004) study that reported 61.8% teachers thought that they had not been exposed sufficiently on how to teach thinking skills.

Analysis of the Think-aloud interview of students on solving an electrochemistry problem:

It was discovered that the students were not elaborate in answering the interview questions. Most of them answered the questions in a short and brief way, making it difficult to discern the respondents’ thoughts. Only those that had been involved in the pilot study (Students 2, 3 and 10) seemed to be more receptive and willing to share their thoughts more openly. Thus, what is analysed and discussed here is the gist of what had been extracted from the limited students’ responses. Most students interviewed (7 out of 10) solved the electrochemistry problems. All three students that failed to solve the problems were from the traditional group (Student 1, 4 and 8). Even though some students of the inductive group had some difficulties in solving the problem (Student 2, 3 and 10), they succeeded to solve it when given some help with the observations. It seemed that they tried to build their understanding from the observations and products of the electrolysis. From there, students were able to generalise the difference between the electrolysis of dilute and concentrated hydrochloric acid, albeit the different phrasing of the generalisations.

In short, the written test results showed that the inductive group performed better than the traditional group. The interviews however revealed that chemistry teachers do not have adequate knowledge and skills to employ the inductive teaching methods in their chemistry classes. Findings from the think-aloud interview also seemed to support that the inductive way of prompting the students also seemed to help the weak students to solve the electrochemistry problems.

The analysis of interview showed how encounters with misconceptions influenced the development of students' reasoning, compared to other encounters during the learning experience. Misconceptions did not constrain the development of students' reasoning. Rather, their reasoning developed in response to the contingencies of the specific situation. When misconceptions were encountered, they appeared as alternatives and questions not actively defended. Sometimes, encounters with these misconceptions were generative of the students' reasoning. The results indicated that demonstrating misconceptions in interviews is not enough to assume that they interfere with learning in other contexts.

Conclusion

The author concluded that the inductive teaching methods would produce students with better ability to solve electrochemistry problems. Learning would also be enhanced if teachers use inductive methods that cause students to experience the related concepts before they begin to lecture over the general theory associated with that concept. It is found learning is enhanced if students have a class experience that causes them to remember and understand the concept. It is recommended that teachers to use specific examples, experiments, and experiences often and, preferably, before trying to explain a general concept.

These findings imply that the science or chemistry teacher training program should look into the matter. Since the inductive teaching methods would facilitate students’ inductive reasoning, the researcher posited that science teachers on the whole or chemistry teachers in particular, should at least have adequate knowledge and skills on the matter. Yet, like any other teaching methods, the inductive method should be employed wisely; otherwise a lot of class valuable time would be wasted on futile and frustrating guessing.

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