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Thai Undergraduate Chemistry Practical Learning Experiences Using the Jigsaw IV Method

Ninna Jansoon
Institute for Innovation and Development of Learning Process
Mahidol University, Thailand

Ekasith Somsook
Faculty of Science
Mahidol University, Thailand

Richard K. Coll
Centre for Science and Technology Education Research
University of Waikato, New Zealand

The research reported in this study consisted of an investigation of student learning experiences in Thai chemistry laboratories using the Jigsaw IV method. A hands-on experiment based on the Jigsaw IV method using a real life example based on green tea beverage was designed to improve student affective variables for studying topics related to dilution. Earlier work by the authors and other published work suggest Thai students' do not much enjoy studying topics such as dilution chemistry and stoichiometry, and the authors wished to develop learning experiences for such topics that students might enjoy more. The Jigsaw method is, however, reasonably complex and the approach used is radically different to normal teaching approaches used in Thai science classes, but is the type of teaching approach recommended in the current Thai science curriculum. Here we reported on 244 Thai first year undergraduate students' learning approaches; their past learning approaches and their learning experiences with a new cooperative learning approach based on the Jigsaw IV method. The research findings, based on self-completion questionnaires and classroom observations suggest that in the past these students did not particularly enjoy learning in chemistry practical classes, and they reported using highly formulaic approaches to solve chemistry problems for dilution. In contrast they enjoyed *the more interactive nature of the Jigsaw IV approach, and in particular acting as an 'expert' in front of their peers, which enhanced their self-confidence about chemistry learning in practical classes. They did, however, struggle to understand the purpose of the new teaching approach based on the Jigsaw IV method.*

Key words: Jigsaw IV method; Attitude toward Chemistry; Dilution; Learning experiences.

Introduction

In the first-year of university study the general chemistry course and associated laboratory classes commonly have high enrolments and students of mixed abilities. In such circumstances students may feel isolated and somewhat 'lost in the crowd'. To counter this, many teachers use small group learning methods in laboratory or tutorial classes. The literature suggests small group learning is useful in several ways. First, individual student differences can be accommodated, the feeling of isolation may be reduced, and active learning is encouraged (Draskovic, Holdrinet, Bulte, Bolhuis, & Van Leeuwe, 2004). At the same time students learn to solve problems (Johnson & Johnson, 2005), and get to share laboratory equipment (Lunetta, 1990). In small group learning activities the teacher is able to employ cooperative learning, which emphasises non-cognitive learning processes such as communication, social skills, and personal development, and at the same time it promotes learning.

Cooperative learning comes in a variety of types. Four notable cooperative learning models used to improve student learning are reported in the literature: *Student Teams-Achievement Division* (STAD), *Teams-Games-Tournament* (TGT), *Jigsaw*, and *Group Investigation* (Lazarowitz & Hertz-Lazarowitz, 1998). All these types of cooperative learning involve students working together in heterogeneous groups. In the STAD method, the teacher presents new material using formal teaching: lectures, discussion, or videos. In groups, the students then work together on a worksheet until they become a 'master'. Each student takes an individual quiz, and their scores are combined to create team scores. The students that become winners are from the group with the highest score. The TGT method is different from the STAD method, in that the quiz and individual improvement scores are replaced with games and a 'tournament'. The Jigsaw method consists of two groups: a home group and an expert group. The lessons are divided into independent sub-lessons that are done in parallel. Each student becomes an expert in one sub-lesson as part of a group investigation. The groups select an interesting topic for investigation, and the students generate questions and then construct their knowledge. The structure of knowledge is hierarchical, and each step can be studied separately and subsequently put together (Lazarowitz & Hertz-Lazarowitz, 1998).

In science education, the Jigsaw method and its variants are reported to be used in classes more often than other collaborative learning methods, especially in biology, chemistry, and physics and the Earth sciences. This is because the Jigsaw method is considered to enhance cooperative learning by making each student focus on a particular topic. Because of this, Aronson and Patnoe (1997) conclude that the Jigsaw method is the most useful collaborative learning method because students must discuss and communicate the meaning of their topics, meaning they develop critical thinking and problem-solving skills. In support of this, Slavin (1990) observes that the Jigsaw method is particularly useful because students must take an active role in learning, something Colosi and Zales (1998) believe occurs because students learn a subject best when they have to explain it to their peers.

Jigsaw Methods

The original Jigsaw method was developed by Aronson and colleagues in 1978, and its mode of operation is now explained in more detail. The method essentially consists of breaking down a large topic into a number of small topics, with the production of an 'expert sheet' prepared by the teacher. The students work in a 'home group' which is heterogeneous in nature. They each are assigned to read an expert sheet, and then those who have the same expert sheet move from the home group to a separate expert group in which they then discuss their topic in detail. Once the discussion in the new group is complete, they return to their home group, and teach all their home group members about the topic that they are now expert in. Finally the groups are assessed, and individual grades are given.

The Jigsaw II method was modified from the original method by Slavin in 1986. This revised version of the method involves using computed team scores as for the STAD method. Aronson and Patnoe (1997) report that Jigsaw II has two substantial changes: all students in the team read all the lessons, and the scores of students are combined to contribute to an overall team score. This method has been used for subjects in the social sciences, and in science - particularly when the learning goals focus on concepts rather than skills (Slavin, 1990).

In the case of Jigsaw III, Gonzalez and Guerrero (1983) modified Jigsaw II to increase the interaction between students. Steinbrink, Walkiewicz and Stahl (1995) note that Jigsaw III has the addition of a cooperative test review process. This cooperative test review involves reconvening the home group and reviewing the process.

Finally, Jigsaw IV, developed by Holliday (2002), includes three important new features: an introduction, quizzes, and re-teaching after individual assessment (Holliday, 2000). In order to stimulate student interest in the lesson, the teacher first introduces the lesson by means of lectures, presentation of literature, questioning, proposing problems, or perhaps showing a movie in a 'plenary' class session. Students are then assigned to a heterogeneous group – the home group – and all students are assigned topics to read. Here each student discusses the expert sheet that is based on a list of all topics. Again, the students with the same expert sheet move to their expert group to discuss their topic. In order to check accuracy and understanding of students in the expert group, they are assessed by means of a quiz – this being based on the expert sheet. They return to their home group, teach all their group members and take quizzes all based on the original material. The teacher reviews and clarifies any concepts which it appears the students did not understand. The students take individual quizzes, and scores are combined to produce an overall team score. Finally, the teacher re-teaches any material which was misunderstood after the individual assessment process.

The Jigsaw, Jigsaw II, Jigsaw III, and Jigsaw IV methods are compared and contrasted in Table 1.

Table 1
Comparison of Jigsaw, Jigsaw II, Jigsaw III, and Jigsaw IV (after Holliday, 2000)

	Jigsaw	Jigsaw II	Jigsaw III	Jigsaw IV
1	-	-	-	Introduction
2	Expert sheet assigned to expert group	Same as Jigsaw I	Same as Jigsaw I	Same as Jigsaw I
3	Member answer expert questions	Same as Jigsaw I	Same as Jigsaw I	Same as Jigsaw I
4	-			Quiz
5	Member return to home group and information	Same as Jigsaw I	Same as Jigsaw I	Same as Jigsaw I
6	-	-	-	Quiz
7	-	-	Review process	Same as Jigsaw III
8		Individual assessment and grade	Same as Jigsaw II	Same as Jigsaw II
9	-	-	-	Re-teaching

According to Holliday (2000), the three important features of Jigsaw IV are the introduction, the quiz, and re-teaching:

1. *Introduction*: The teacher introduces the lesson by means of lectures, literature, questions, problems or showing a movie. The purpose here is to stimulate student interest in the lesson;
2. *Quiz:* The students are evaluated by means of two quizzes:
   - The first quiz is designed to check the accuracy and understanding of student in the expert group - this based on the expert sheet.
   - The second quiz is designed to check accuracy and understanding of students in the home group - this based on all original material; and
3. *Re-teach:* The teacher re-teaches the material which they think has been misunderstood based on the individual assessment process.

Holliday (2002) goes on to say that class activities can be sorted into nine processes.

1. *Introduction*. The teacher introduces the principle and experiment to the students in a plenary session, and assigns students to a home group, containing six students. The members of each home group are divided into expert groups;
2. *Expert sheets assigned to expert groups*;
3. *Answer expert questions prior to returning to home group*. The students are asked questions based on their expert sheet to check their understanding prior to returning to their home group;
4. *Quiz on material in the expert groups checking for accuracy*. The teacher administers quizzes to assess the validity of their responses;
5. *Return to home groups to share their information with their group*. The students return to their home group to teach their peers, and to share information with each other in their home group;
6. *Quiz on material shared, checking for accuracy.* The students are asked questions based on all original material;
7. *Review process*. The teacher reviews and clarifies any concepts which it appears the students did not understand;
8. *Individual assessment and grade*. Each student is reassessed using a post-test; and
9. *Re-teach*. The teacher re-teaches any topics found to be difficult based on the post-test assessment.

In summary, in all of the Jigsaw methods students are assigned to study specific topics in an expert group, they become the expert on their topic, and subsequently they teach all their home group members. This means they have the opportunity to teach and learn in their groups, they are able to share their ideas, they develop their self-confidence, cooperation and motivation (Barbosa, Jofili, & Watts, 2004). In other words, the students are able to improve in both cognitive and affective ways (Eilks, 2005). As noted earlier, the Jigsaw methods are used in science classes more than other collaborative learning methods, because the structure of much science knowledge is hierarchical, meaning each step can be studied separately and then put together – like a jigsaw! (Lazarowitz & Hertz-Lazarowitz, 1998).

Research suggests that students improve in terms of attitude towards science, at the same time they achieve cognitively (Eilks, 2005). In particular, it seems students improve their critical-thinking skills (Aronson & Patnoe, 1997; Ulrich & Glendon, 1995), and are able to approach the critical thinking process involving: analysis, reflection, synthesis, and reconstruction (Charania, Kausar, & Cassum, 2001; Ulrich & Glendon, 1995). Overall then, although the Jigsaw method is a rather complicated teaching approach, students are able to develop critical thinking skills (Charania et al., 2001), and learn how to lead discussions (Colosi & Zales, 1998).

The Jigsaw method has been reported to improve affective variables for a variety of science students. For example, in introductory chemistry laboratory courses, Smith, Hinckley and Volk (1991) used the Jigsaw method to address a lack of student preparation, and poor understanding of chemistry concepts for acid/base chemistry. Here the students had to conduct a part of the experiment, and share their data, and the results from their groups. It seems the Jigsaw method had a positive effect on the laboratory class, and in particular for low-achieving students who showed the greatest gains in post-tests of conceptual understanding. In addition, the literature suggests the Jigsaw methods also work well for abstract topics like atomic structure. Eilks (2005), for example, reports on the use of Jigsaw II to teach atomic structure in grade 9 and 10 chemistry classes. In this study, students were required to read the text, do an experiment, and explain some models for atomic structure. It seems students were more attentive in the classes, and enjoyed science lessons – pointing to affective gains. They said they enjoyed working in small groups, and felt they had more freedom to make individual or group decisions. Charania et al. (2001) likewise investigated student perceptions of learning in a Jigsaw method-based class, and report that when students discussed their specific topic within their expert group, they increased in conceptual understanding, developed self-confidence, and enhanced communication skills. Of particular interest to chemistry teachers is the fact that the Jigsaw method is reported to work well for the teaching of problematic topics that involve shifting from macroscopic to microscopic levels of representation (Johnson, 1990). Fleming (1995) investigated the effectiveness of cooperative learning in a microscale laboratory, and reported that when students discussed organic chemistry topics within their groups, they could better solve difficult problems, and understood and enjoyed their classes more.

Although the use of the Jigsaw method has been reported for a variety of science topics, little is known about how it might enhance affective variables for topics student typically do not enjoy, such stoichiometry and numerical-based chemistry topics like dilution chemistry. Research within our group indicated that Thai students do not much enjoy studying dilution topics and we were interested to see if Jigsaw could improve affective variables. We now consider the literature about dilution chemistry before describing the nature of the study and the intervention based on the Jigsaw method.

Dilution and Concentration

An understanding of dilution methods is a key requirement for much practical chemistry, because most reaction and synthetic chemistry involves making up solutions, and often carrying out dilutions or combining solutions. Students need to be able to prepare standard solutions, and make diluted solutions from these (Dunnivant, Simon, & Willson, 2002; McElroy, 1996; Wang, 2000). Understanding dilution actually requires knowledge of quite a few other related concepts such as concentration, solvent, solute, solution, solubility, and of course the mole. Therefore, in order for students to understand dilution, they have to understand the mole concept as well as the concepts of solution and concentration. Although the mole is a central topic in both secondary school and higher education, students at all academic levels use it to relate a variety of topics such as preparation of solutions, dilution, concentration units, and titration. The mole is a concept that the literature suggests students have many difficulties understanding (see, e.g., Case & Fraser, 1999; Heyworth, 1999; Novick & Nussbaum, 1976; Staver & Lumpe, 1995). It seems this is, at least in part, due to inadequate understanding of the meaning of the mole, and overuse of formulae in mole-based problem-solving. For example, students commonly exhibit weak understanding of underlying concepts, instead simply resorting to the use of algorithms. Constant adherence to this algorithms may mean that students misunderstand things such as the amount of substance and the concentration present before and after dilution of solutions (Demeo, 1996; Raviolo, 2004).

One way of enhancing student interest in studying topics like dilution chemistry is via more hands-on activities such as in laboratory classes. The literature suggests students generally enjoy working in chemistry laboratories, and that practical work can enhance students' interest in science (Nakhleh, Polles, & Malina, 2002). However if the experiments are artificial and disconnected from daily life, then practical work can have the opposite effect (Lozano-Calero & Martin-Polomeque, 1996). It seems that non-majors (i.e., students who study chemistry not intending to complete a degree majoring in the subject) feel they do not need basic chemical knowledge for their fields of interest (Loyo-Rosales, Torrents, Rosales-Rivera, & Rice, 2006), and are particularly put off if the practical work is not related to daily life.

A variety of techniques have been employed in order to motivate students and to maintain their interest in chemistry practical classes. One approach is to use real-world examples (Jones & Miller, 2001) so that students come to see that chemistry is related to everyday life, and not some abstract study of concepts outside everyday life experiences. Green tea is such a real-world example; it is a beverage that is widely consumed worldwide, and especially in Asian nations including Thailand, the context for this study. In green tea total phenolics are determined using the well-established Folin-Ciocalteu method (Singleton & Rossi, 1965) because of its reliability, and the fact that is uses fairly simple equipment making it cost-effective. It is an appealing method for use in senior school and undergraduate laboratories for a variety of reasons. For example, it uses only two chemicals: sodium carbonate and the Folin-Ciocalteu reagent. It also is quick, and so is suitable for introductory chemistry practical classes (George, Brat, Alter, & Amiot, 2005). In using this method students get to practice basic chemistry skills such as dilution methods, and making up solutions, and also new topics such as the preparation of calibration curves, and the use of equipment such as a UV-visible spectrometer.

Context of the Study: Science and Chemistry Education in Thailand

The Thai National Education Plan states that all Thai citizens have an equal right to receive an education. As a result of the National Scheme of Education of 1992, the Thai education system is divided into four levels: primary, lower secondary, upper secondary, and higher education, with pre-school education also provided before formal schooling begins. In 1997, the Thai Constitution stated that citizens must receive basic government-funded education for at least 12 years. Science schooling thus nowadays consists of six-years primary, three-years lower secondary and three-years upper secondary education.

This study was conducted in a prestigious university in Thailand. All first-year chemistry students enroll in a chemistry laboratory course in which they conduct experiments related to lectures such as the determination of the gas constant, crystal models, freezing point depression, thermochemistry, determination of an order of reaction and acid-base titration. They also learn general chemistry techniques, how to use basic experiment, and how to make dilutions and prepare solutions. Dunnivant et al. (2002) suggest that one key goal of introductory undergraduate chemistry practical courses is to teach the students to make dilutions and prepare solutions, and this formed the basis of this work.

Research Purpose and Research Questions for the Inquiry

As noted earlier, a number of authors have commented on the value of the use of the Jigsaw IV Method in science classrooms, especially for topics like dilution that are hierarchical in nature, for which each topic can be studied separately, and then be put together. This research focuses on first year undergraduate students at a prestigious Thai University.

The purpose of research is to thus investigate the use of the Jigsaw IV method to enhance student affective variables when studying dilution concepts. First we wished to understand students' attitude towards chemistry, prior learning approaches, and knowledge of practical chemistry. This was deemed important because of the context of the study. As noted about the Thai science curriculum is supposedly learner-centered – consistent with the planned intervention based on the Jigsaw method. However, other research (e.g., Dahsah & Faikhamta, 2008) indicate that this is often not the case, and much teaching remains teacher centered. Hence, to contextualise our findings we sought to understand the students' background and prior ideas. Specifically, the research sought to:

1. Develop an understanding of Thai undergraduate students' attitude towards chemistry, prior learning experiences, and knowledge of practical chemistry prior to an intervention based on the Jigsaw IV method;
2. Design a hands-on experiment based on Holliday's (2002) Jigsaw IV method to teach dilution and related topics in the general chemistry laboratory; and
3. Evaluate Thai first year undergraduate chemistry students' attitudes and perceptions of learning dilution chemistry after the application of the Jigsaw IV method.

Methodology

Theoretical Framework

Constructivism and social constructivism are important theories used in much science education research (Driver, Asoko, Leach, Mortimer, & Scott, 1994; Duit & Treagust, 1998; Solomon, 1994). According to constructivism, students construct knowledge using cognitive processes (Wheatley, 1991). According to constructivists, effective learning does not involve transmission of knowledge from the teacher to the student, but is instead an active process in which students are engaged in learning. Social constructivism builds on this notion of personal construction of knowledge, and recognises the importance of social interactions in the learning process. Hence, from a social constructivist point of view, learning is built upon student prior knowledge, and involves interaction with a teacher and peers. Student learning via cooperation in which they share a way of doing things and intend to achieve the same goal is consistent with constructivism, and social constructivism in particular. According to Vygotsky (1978), knowledge is socially-constructed in a cooperative effort to learn, understand, and solve problems. Vygotsky (1978) proposed the zone of proximal development (ZPD) in which development occurs though problem-solving under adult guidance or "in collaboration with more knowledgeable others" (Johnson & Johnson, 2005 p. 86). In a similar way, Piaget (1964), suggests that when individuals cooperate on group learning, sociocognitive conflict can occur, and when the students engage in meaningful discussion, this conflict can be resolved in the particular social setting.

Research Design

The authors designed a new experiment to determine total phenolic compounds in green tea beverage samples based on the Folin-Ciocalteu method. This experiment was intended to teach the students about dilution and related topics. The experiment was divided into two parts. Part A involved students preparing standard solutions and creating a calibration curve, and Part B involved students determining total phenolic compounds in some green tea beverage samples.

The authors divided the experiment into three topics and prepared three expert sheets. The activity was designed based on the nine processes identified by Holliday (2002) for use with the Jigsaw IV method:

- *Process 1: Introduction.* The teacher introduced the principle and experiment to the students in a whole class setting. The teacher assistant assigned students to a mixed-ability home group, containing six students. The members of home groups were divided in to three expert groups: Group I; Group II; and Group III.
- *Process 2: Expert sheets assigned to expert groups*. All members in the same expert group moved into their expert group and received their expert sheet:
  - Group I received the expert sheet Part A;
  - Group II received the expert sheet Part B-1; and
  - Group III received the expert sheet Part B-2.

  The students then studied and discussed their topics as presented in the expert sheets.
- *Process 3: Groups answer expert questions prior to returning to home group*. The students were asked questions based on their expert sheet to check their understanding prior to returning to the home group.
- *Process 4: Quiz on material in the expert groups checking for accuracy*. The teaching assistants administered quizzes to assess the validity of student responses.
- *Process 5: Students return to home groups, sharing their information with team-mates*. The students returned to their home group to teach their peers, and to share information with each other in their home group.
- *Process 6: Quiz on material shared, checking for accuracy*. The teaching assistants discussed the data, and questions with the home group to check validity of the results; that is, the determination of the total phenolic content of green tea beverages.
- *Process 7: Review process.* The teaching assistants reviewed and clarified any concepts which it appeared the students did not understand.
- *Process 8: Individual assessment and grade*. Each student was then reassessed using a post-test.
- *Process 9: Re-teach any material missed on assessment as needed.* The teaching assistants re-taught any sections found to be difficult from the post-test assessment.

Data Collection

Data collection consisted of questionnaires of student perceptions of the intervention used to measure affective variables, and observation of the classes by the first author.

The questionnaire used to evaluate affective variables consisted of 24 items, 15 items related to student perceptions before doing the experiment, and 9 items related to student perceptions after doing the experiment. Each item consisted of a four-point Likert scale (4=Strongly Agree, 3=Agree, 2=Disagree, and 1=Strongly Disagree), and respondents were asked to indicate their level of agreement or disagreement with the items. So before doing the experiment, questions were asked to determine student attitude towards chemistry, and prior knowledge about dilution and related concepts: concentration, solutions, mole, UV-Visible spectrometer, calibration graphs and green tea. After performing the experiments, the questionnaire investigated student perceptions about the new experiment and learning experiences.

The questionnaire was developed in English and then translated into Thai by a chemist bilingual in Thai and English. In order to ensure the original meaning was retained, the first two authors and the translator discussed the questionnaire in detail, and several items were reworded slightly. In addition, a panel of judges consisting of three instructors who had taught university chemistry for more than 10 years checked the translated items for clarity and face validity, and these discussions were subsequently used to refine the questionnaire.

Sample

The sample consisted of 244 first-year students enrolled in the usual first year chemistry laboratory course in the science faculty at a prestigious Thai University. The students consisted of both chemistry majors and non-majors, who were varied in terms of their academic ability (based on performance in entry requirements) and learning backgrounds (evidenced by a significant spread in geographical origin – e.g., rural vs. city, etc.).

Research Findings

As noted previously the dilution concept is a very useful part of practical introductory chemistry, but the learning demands on students are surprisingly significant. Students need to know how to make diluted solutions, and to prepare standard solutions of particular concentrations.

To do these tasks requires them to draw on other, related concepts such as the mole, and to do a number of algebraic manipulations. As a consequence, their attitude towards chemistry may be related to their achievement in such tasks conducted previously. These students all studied these topics in upper-secondary school before coming to university, but they varied significantly in terms of background and prior learning experiences. As a consequence, before doing the experiments, the researchers investigated the students' attitude towards chemistry, and reported prior learning approaches to dilution chemistry using the purpose-designed questionnaire described earlier. The students' perceptions are shown in Table 2.

Attitude toward Chemistry, and Prior Learning Approaches to Dilution Chemistry

These first-year undergraduate science students had a relatively positive attitude toward chemistry before doing the experiment based on the Jigsaw IV approach (Table 2, item 1). They also reported that they knew about dilution concepts (item 2), the meaning, objectives, processes, and methods used to make up solutions or do dilutions (items 3-5) because they had studied about them in upper secondary school. More than half of the students in classes reported that they liked to use the equation $C_1V_1=C_2V_2$ to calculate dilutions (items 6-7). Some students did report they liked to calculate the concentration using a different method (the 'step-by-step' approach). Some of the students reported that they analysed samples using UV-visible spectroscopy previously, in upper secondary school, and felt they knew how to interpret data using a calibration graph (items 10-11). However, fewer than half of the students reported that they knew about the technique of UV-visible spectroscopy and about calibration graphs. Finally, the students said they were used to drinking green tea beverages (item 14), knew about the purported advantages of drinking green tea beverages (item 15), but were not familiar with the chemical composition of green tea (item 12).

Table 2
Thai First Year Chemistry Undergraduate Students' Attitude towards Chemistry, Prior Learning Approaches to Dilution Chemistry, and Knowledge of Practical Chemistry *(N=244)*

	Item	SA+A (%)	SD+D (%)
1	I think chemistry is a very interesting subject	96	4
2	I knew about dilutions before doing this experiment	91	9
3	I felt I understood why we need to know how to dilute solutions before doing this experiment	80	20
4	I felt I understood how to make dilutions of stock solutions before doing this experiment	80	20
5	I felt I understood how to calculate concentrations before doing this experiment	71	29
6	I had already used the formula $C_1V_1=C_2V_2$ to calculate dilutions before doing this experiment	80	20
7	I knew what the formula $C_1V_1=C_2V_2$ means before doing this experiment	64	36
8	Before doing this experiment, I would calculate the concentration of solutions by another method (open response with description of other methods also solicited)	36	64
9	I was familiar with the technique of UV-Visible Spectroscopy before doing this experiment	29	71
10	I was familiar with calibration graphs before doing this experiment	53	47
11	Before doing this experiment, I knew why we need to draw calibration graphs	67	33
12	I was familiar with phenols before doing this experiment	34	66
13	I was familiar with green tea before doing this experiment	98	2
14	I used to drink green tea beverages before doing this experiment	96	4
15	I knew about the advantages and disadvantage of green tea beverages before doing this experiment	84	16

Key: SA=strongly agree; A=agree; D=disagree; SD=strongly disagree

Perceptions of Learning Dilution Chemistry Based on the Jigsaw IV Approach

Student perceptions of their learning of dilution chemistry via the Jigsaw IV approach are reported in Table 3. In the Jigsaw IV approach as applied to these practical classes, the students worked together in groups, and employed more interactive learning strategies. In particular, each student became an 'expert' for a specific topic, and subsequently taught this to his or her home group.

Table 3
Thai First Year Undergraduate Chemistry Students' Perceptions of Learning Dilution Chemistry via the Jigsaw IV Method (N=244)

	Item	SA+A (%)	SD+D (%)
1	In this experiment, I felt I learned how to make dilutions of stock solutions	96	4
2	In this experiment, I felt I learned how to calculate the concentration of solutions	90	10
3	In this experiment, I felt I understood clearly about the concentration of solutions	82	18
4	In this experiment, I felt I learned how to use the UV-visible spectrometer	94	6
5	In this experiment, I felt I learned how to draw a calibration curve	87	13
6	In this experiment, I felt I learned how to calculate the concentration of total phenols in green tea beverages	89	11
7	In this experiment, I felt I learned more about total phenols in green tea beverages	81	19
8	In this experiment, I liked using the Jigsaw IV Method(open response with description of things liked and not liked also solicited)	49	51
9	In this laboratory, I felt happy and relaxed (open response with description of things liked and not liked also solicited)	38	62

Key: SA= strongly agree; A= agree; D=disagree; SD=strongly disagree

There are some unusual features to these data. First, the students were in fact not very positive overall about their learning experiences with the Jigsaw approach (items 8-9). However, in contrast, they felt strongly that the experiment helped them understand dilution chemistry (item 1), concentration (item 2-3), how to use the UV-visible spectrometer (item 4), the use of calibration curves (item 6), and how to calculate total phenols in green tea beverages (item 7). It is clear then that the students had a better understanding about the dilution method, the solution concentration, the UV-visible spectrometer, calibration graph, and phenols in green tea.

Overall fewer than half of the students said they liked the method, and were happy and relaxed in their class. In the open responses to this item some students said they did not really understand the Jigsaw IV method. To the following item (i.e., item 9) open responses indicated the students felt they could not manage time and their groups generally. This is most likely because this method was used for the first time in these experiments.

Summary and Conclusions

We first note that this research study is a case study in nature. Guba and Lincoln (1989) suggest that a case study can be of value to readers provided the authors provide a detailed audit trail of the background, context, research design and findings. The intention then is for the reader to compare the reported findings with his or her own education context and engage in transfer of relevant lessons to be learned from the case study. We also note that this work is a one-off intervention in a particular educational context. It is not different to other case studies or interpretive studies (see Merriam, 1988). However, Munby (1997) comments that there are dangers in assuming enhancement of affective variables are sustained in nature. Hence, here as in any case study, readers are urged to exercise caution in drawing any generalisations.

The literature suggests that hands-on collaborative learning activities, like the Jigsaw IV method, work best when they are applied to experiments which have multiple topics: in this case, dilution methods; concentration of solutions; preparing calibration graphs; and calculating the phenol content in green tea beverages. In these practical classes based on the Jigsaw IV method, the students were first required to study a specific topic. In this case, some students acted as the expert and then they taught their peers in their home groups. Unobtrusive observation of the lessons by the first author indicated that students who were able to lead the reflection, synthesis, and reconstruction in the expert group as suggested by Ulrich and Glendon (1995), were those best able to teach their peers when they returned to their home group. In particular, the Jigsaw IV method includes three important features: introduction, quizzes, and re-teaching, which ensured that the teachers had opportunities to assess their students using formative assessment. In this work the students were new to practical classes generally, and had come from very different learning backgrounds. One intention here then was to help develop their self-confidence, motivation, and ability to learn cooperatively. The findings reported here suggest the students gained in self-confidence after completing the experiments. The students felt they had learned more, and understood about dilution, solution concentration and how to use a UV-visible spectrometer, as well as how to prepare calibration graphs, and calculate the concentration of phenols in green tea beverages.

It seems that a reasonable proportion of the students did not like to use the Jigsaw IV – this was somewhat of a surprise given reports in the literature that students generally enjoy practical work and more active learning strategies (Johnson & Johnson, 2005), and indeed cooperative learning strategies such as group work (Lazarowitz & Hertz-Lazarowitz, 1998). Here we suggest there are two main reasons why these students might not have enjoyed Jigsaw as much as anticipated. First, is the educational context; namely the Thai education system. As noted above, and as reported in the literature (Dahsah & Faikhmata, 2008), students are much more accustomed to passive learning in which the teacher gives clear directions and controls the learning environment. This is particularly true in the case of Thai students (Dahsah & Coll, 2008). Whilst one might think this is more of an issue in school, Coll, Taylor and Fisher (2002) noted that this is also true even in higher education where students are expected to become more independent learners. However, Coll et al. (2002) reported that many students, especially academically-able students, prefer the teacher to exercise control over the classroom and learning activities, because this results in greater clarity about what is needed to be done to succeed in assessment tasks. Vulliamy (1988) commented that success in higher education in many developing countries is of high priority, as exams and test serve as gatekeepers for future careers.

Second, it is possible that the students did not really understand the purpose of the method. This is in fact consistent with the literature, which suggest one common problem of cooperative learning methods lies in students actually understanding the processes, and roles of participants (Balfakih, 2003). If the purpose of the new approach is not made explicit, it seems students and indeed teachers may focus on the new activity and fail to grasp its purpose and thereby value in the learning process. This was no doubt exacerbated in the present work because the learning environment was so very different to what Thai school students typically experience (see Dahsah & Faikhamta, 2008), and indeed undergraduate university students experience (Dahsah & Coll, 2007; 2008). In addition, some of the student participants felt they spent too much time when learning by the Jigsaw IV method. Likewise, the teaching assistants also felt they spent too much time preparing the activities and procedures, something the literature suggest is a common perceived barrier to new, particularly constructivist-based learning approaches, like the Jigsaw method (see Colosi & Zales, 1998). Dahsah and Coll (2007) report that learner-centered teaching approaches such as Jigsaw are very new for Thai teachers, who typically only pay lip service to learner-centered education. If this is the case, then it also is possible that the teachers did not really understand the purpose of the intervention; only seeing it as a convenient way of assuring their superiors that they were indeed engaged in learner-centered education.

In conclusion it seems there were some useful gains in student learning experiences, but that teachers and students both need more experience in cooperative learning before they become familiar enough to appreciate improvements in self-confidence about learning practical chemistry that seem to accrue (Charania et al., 2001). In particular they need to understand the purpose of using cooperative learning approaches such as Jigsaw meaning they can indeed deliver a learner-centered education in the way required by Thai education authorities. Hume and Coll (2008) suggest that any new teaching approach requires time for all parties to become accustomed to it before its full potential can be realised.

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References

Aronson, E., & Patnoe, S. (1997). *The jigsaw classroom: Building cooperation in the classroom*. New York: Longman.

Balfakih, N. M. A. (2003). The effectiveness of student team-achievement division (STAD) for teaching high school chemistry in the United Arab Emirates. *International Journal of Science Education, 25*(5), 605-624.

Barbosa, R., Jofili, Z., & Watts, M. (2004). Cooperating in constructing knowledge: Case studies from chemistry and citizenship. *International Journal of Science Education, 26(8), 935-949*.

Case, J. M., & Fraser, D. M. (1999). An investigation into chemical engineering students' understanding of the mole and the use of concrete activities to promote conceptual change. *International Journal of Science Education, 21*(12), 1237-1249.

Charania, N., Kausar, F., & Cassum, S. (2001). Playing jigsaw: A cooperative learning experience. *Journal of Nursing Education, 40*(9), 420-421.

Coll, R., Taylor, N., & Fisher, D. (2002). An application of the Questionnaire on Teacher Interaction and College and University Classroom Environment Inventory in a multicultural tertiary context. *Research in Science and Technological Education*, *20*(2), 165-183.

Colosi, J. C., & Zales, C. R. (1998). Jigsaw cooperative learning improves biology lab courses. *Bioscience, 48*(2), 118-124.

Dahsah, C., & Coll, R. K. (2007). Thai Grade 10 and 11 students' conceptual understanding and ability to solve stoichiometry problems. *Research in Science and Technological Education, 25*(2), 227-241.

Dahsah, C., & Coll, R. K. (2008). Thai Grade 10 and 11 students' understanding of stoichiometry and related concepts. *International Journal of Science and Mathematics Education, 6*(3), 573-600.

Dahsah, C., & Faikhamta, C. (2008). Science education in Thailand: Curriculum reform in transition. In R. K. Coll & N. Taylor (Eds.), *Science education in context: An international examination of the influence of context on science curricula development and implementation* (pp. 291-300). Rotterdam: Sense Publishers.

Demeo, S. (1996). Mathematically modeling dilution. *The Chemical Educator, 1*, 1-5.

Draskovic, I., Holdrinet, R., Bulte, J., Bolhuis, S., & Van Leeuwe, J. (2004). Modeling small group learning. *Instructional Science, 32*(6), 447-473.

Driver, R., Asoko, H., Leach, J., Mortimer, E., & Scott, P. (1994). Constructing scientific knowledge in the classroom. *Educational Researcher, 23*(7), 5-12.

Duit, R., & Treagust, D. F. (1998). Learning in science-from behaviourism towards social constructivism and beyond. In B. J. Fraser & K. G. Tobin (Eds.), *International handbook of science education* (pp. 3-25). Dordrecht: Kluwer.

Dunnivant, F. M., Simon, D. M., & Willson, S. (2002). The making of a solution: A simple but poorly understood concept in general chemistry. *The Chemical Educator 7*(4), 207-210.

Eilks, I. (2005). Experiences and reflections about teaching atomic structure in a jigsaw classroom in lower secondary school chemistry lessons. *Journal of Chemical Education, 82*(2), 313-319.

Fleming, F. F. (1995). No small change: Simultaneously introducing cooperative learning and microscale experiments in an organic lab course. *Journal of Chemical Education, 72*(8), 718-729.

George, S., Brat, P., Alter, P., & Amiot, M. J. (2005). Rapid determination of polyphenols and vitamin C in plant-derived products *Journal of Agricultural and Food Chemistry, 53*(5), 1370-1373.

Guba, E., & Lincoln, Y. (1989). *Fourth generation evaluation*. Newbury Park, CA: Sage.

Gonzalez, A., & Guerrero, M. (1983). *Jigsaw teacher's handbook*. Hollister, CA: Hollister Unified School District.

Heyworth, R. M. (1999). Procedural and conceptual knowledge of expert and novice students for the solving of a basic problem in chemistry. *International Journal of Science Education, 21*(2), 195-121.

Holliday, D. C. (2000). *The development of Jigsaw IV in a secondary social studies classroom.* Lanham, MD: University Press of America.

Holliday, D. C. (2002). *Jigsaw IV: Using student/teacher concerns to improve Jigsaw III.* Lanham, MD: University Press of America.

Hume, A., & Coll, R.K. (2008). Student experiences of carrying out a practical science investigation under direction. *International Journal of Science Education*, *30*(9), 1201-1228.

Johnson, A. W. (1990). The year-long first course in organic chemistry. *Journal of Chemical Education, 67*(4), 299-303.

Johnson, D. W., & Johnson, R. T. (2005). Learning groups. In S. A. Wheelan (Ed.), *The handbook of group research and practice* (pp. 441-461). Thousand Oaks, CA: Sage.

Jones, M. B., & Miller, C. R. (2001). Chemistry in the real world. *Journal of Chemical Education, 78*(4), 484-487.

Lazarowitz, R., & Hertz-Lazarowitz, R. (1998). Cooperative learning in the science curriculun. In B. J. Fraser & K. G. Tobin (Eds.), *International handbook of science education* (pp. 449-469). Dordrecht: Kluwer.

Loyo-Rosales, J. E., Torrents, A., Rosales-Rivera, G. C., & Rice, C. P. (2006).

Linking laboratory experiences to the real world: The extraction of octylphenoxyacetic acid from water, *Journal of Chemical Education, 83*(2), 248-249.

Lozano-Calero, D., & Martìn-Palomeque, P. (1996). Determination of phosphorus in cola drinks, *Journal of Chemical Education, 73*(12), 1173-1174.

Lunetta, V. N. (1990). Cooperative learning in science, mathermatics, and computer problem solving. In M. Gardner, J. G. Greeno, F. Reif, A. H. Schoenfeld, A. Disessa & E. Stage (Eds.), *Toward a scientific practice of science education* (pp. 235-249). Hillsdale, N.J.: Lawrence Erlbaum Associates.

McElroy, L. J. (1996). Teaching dilutions. *Journal of Chemical Education, 73*(8), 765-766.

Merriam, S.B. (1988). *Case study research in education*. San Francisco, CA: Jossey-Bass).

Munby, H. (1997). Issues of validity in science attitude measurement. *Journal of Research in Science Teaching*, *34*, 337–341.

Nakhleh, M. B., Polles, J., & Malina, E. (2002). Learning chemistry in a laboratory environment. In J. Gilbert, O. D. Jong, R. Justi, D. Treagust & J. H. v. Driel (Eds.), *Chemical education: Towards research-based practice* (pp. 69-94). Dordrecht, The Netherlands: Kluwer Academic Publishers.

Novick, S., & Nussbaum, J. (1976). A study of student perceptions of the mole concept. *Journal of Chemical Education, 53*, 720-722.

Piaget, J. (1964). Cognitive development in children: Development and learning. *Journal of Research in Science Teaching, 2*, 176-186.

Raviolo, A. (2004). An analogic model for understanding the preparation of volumetric solutions. *The Chemical Educator, 9*, 211-215.

Singleton, V. L., & Rossi, J. A. (1965). Colorimetry of total phenolics with phosphomolybdic-phosphotungstic acid reagents. *American Journal of Enology Viticulture, 16*, 144-158.

Slavin, R. E. (1990). *Cooperative learning: Theory, research, and practice*. Englewood Cliffs, NJ: Prentice Hall.

Smith, M. E., Hinckley, C. C., & Volk, G. L. (1991). Cooperative learning in the undergraduate laboratory. *Journal of Chemical Education, 68*(5), 413-415.

Solomon, J. (1994). The rise and fall of constructivism. *Studies in Science Education, 23*, 1-19.

Staver, J. R., & Lumpe, A. T. (1995). Two investigations of students' understanding of the mole concept and its use in problem solving. *Journal of Research in Science Teaching, 32*(2), 177-193.

Steinbrink, J. E., Walkiewicz, S. K., & Stahl, R. J. (1995). Jigsaw III = jigsaw II + cooperative test review: Applications to the language arts classroom. In R. Stahl (Ed.), *Cooperative learning in language arts: A handbook for teachers* (pp. 159-179). Menlo Park, CA: Addison-Wesley.

Ulrich, D., & Glendon, K. (1995). Jigsaw: A critical-thinking experience *Nurse Educator, 20*(3), 6-7.

Vygotsky, L. (1978). Interaction between learning and development. In Gauvain & Cole (Eds.), *Readings on the development of children* (pp. 34-40). New York: Scientific American Book.

Wang, M. R. (2000). An introductory laboratory exercise on solution preparation: A rewarding experience. *Journal of Chemical Education, 77*(2), 249-250.

Wheatley, G. H. (1991). Constructivist perspectives on science and mathematics learning. *Science Education, 75*(1), 9-21.

Authors:

Ninna Jansoon, Institute for Innovation and Development of Learning Process, Mahidol University, Thailand

Ekasith Somsook, Faculty of Science, Mahidol University, Thailand

Richard K. Coll, Centre for Science and Technology Education Research, University of Waikato, New Zealand