Assessing Students' Reflective Responses to Chemistry-Related Learning Tasks

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Abstract

Key to renewed concern on the affective domain of education (Fensham, 2007) and on school graduates' readiness for a world of work (DEST, 2006; WDA, 2006) is the student's inclination-to-reflect when engaged in a learning or problem-solving task. Reflective learning and assessment are not new to education (Dewey, 1933; Ellis, 2001).

Since the inclination-to-reflect may not be strong even for adults at work (Seibert & Daudelin, 1999), what more can educators expect from school students? This paper presents part of a research on secondary school students' inclination-to-reflect while engaged in chemistry learning tasks. The instrument used is the three-part Chemistry Learning and Thinking Instrument, or CLTI. The first part seeks to characterize students' inclination-to-reflect while attempting chemistry learning tasks and the other parts aim to characterize their learning-thinking preferences in the subject. This paper shares the construction of the learning tasks and how students' reflective responses to these tasks are encouraged, scored and analyzed. Since assessment is said to drive teaching and learning, an alternative form of assessment, such as these CLTI items, may help students become more reflective in their learning habits and hence more adaptable to the world of work.

Key Phrases

Affective Science Education; Chemistry Learning and Thinking Instrument (CLTI); Inclination-to-reflect; Reflective learning.

Introduction

Renewed concerns on the affective domain of education (Fensham, 2007) and on school graduates' readiness to enter the world of work (DEST, 2006; WDA, 2006) point to an important development in the way students are being prepared in school – their approaches to solving problems. Being reflective is a well-known thinking habit among scientists. Good examples include renowned ones like Isaac Newton (1643-1727, discoverer of gravity), Gregor Mendel (1822-1884, the father of hereditary science) and August Kekulé (1829-1896), who first proposed the molecular structure of benzene in 1865. Being reflective is also encouraged and recognised as an essential habit among good problem solvers (Stroulia & Goel, 1994) and effective managers at work and in everyday life (Brockbank, McGill & Beech, 2002; Covey, 1989; Harrison, 2006). Assessment is often said to drive learning habits (Enger & Yager, 2001; Gronlund & Waugh, 2008). It may therefore be useful to consider assessing students' inclination-to-reflect so that students can be encouraged to become habitual reflective learners. Hopefully, this will also better prepare them for a more complex and demanding world of work.

This paper presents a part of a research on secondary school students' inclination-to-reflect while engaged in Chemistry learning tasks. The instrument used is the three-part Chemistry Learning and Thinking Instrument, or CLTI. The first part seeks to characterize students' inclination-to-reflect while attempting Chemistry learning tasks and the other two parts aim to characterize their learning-thinking preferences in the subject. This paper shares the first part of the CLTI and how students' reflective responses to these learning tasks are scored and compared. The purpose is not to report in detail the findings of the research but to share a possible alternative way of assessing students' ability to solve problems or respond to learning tasks in school Chemistry.

Reflective Learning Defined

The reflective approach in learning is not a new idea in education. Renowned educationist, John Dewey (1859-1952) had written about reflective thinking and the education of man in 1933. Dewey's work suggests that to understand our life experiences better, we can "… take stock of the conditions before suggestions arise of possible course of action (p.102-103)". This involves the learner taking time to pause and look into the future, recapturing past experiences and establishing a relationship between these experiences and thoughts on a new basis. The *Experiential Learning Cycle* was then proposed by David Kolb as a model of learning with reflection as a key element supporting the process of learning (Kolb, 1984). The model explains how reflecting on experiences helps to further develop the person's learning capacity. However, among the earliest recorded works relating to reflective learning are those of Socrates, the great 5th Century B.C. Greek philosopher. Socrates once said, "the unexamined life is not worth living". Though this may sound harsh, it is undeniable that the human race would not have made the progress we see now if people had not been observant of their surrounding, asked the appropriate questions and generated possibilities to work on so that our lives can be more comfortable.

The literature may be extensive and reaches far back in history but few were empirical studies about the intervening applications of reflective learning strategies. The bulk of reported work on reflective learning reported, however, deal mainly with adult learning and professional practices (Branch & Paranjape, 2002; Loughran, 1996; Moon, 2004; Pollard, 2002; Schön, 1983, 1987; Seibert & Daudeline, 1999; Tan & Ee, 2004; Taylor, 2006). Those that relate to younger learners and school students appear to be reports on best practices or sharing of a variety of learning-teaching strategies (Trudeau & Harle, 2006; Wilson & Jan, 1993). However, two important precursors to reflection are frequently reported: *time* and *experience*. Reflective learning may then be described or defined as a form of learning that requires the learner to pause and observe her/his learning situation, by considering past relevant experiences and generating useful information from that situation. The learner can then make sense of the learning process by linking the past, the present and/or the future.

Reflective Learning Applied

Many reflective learning strategies have been suggested or described as applicable in a classroom or science laboratory setting (Ellis, 2001; Fogarty, 1994; Tan, 2002, 2005, 2007; Whitaker, 1995; Wilson & Jan, 1993). Practising classroom teachers are probably familiar with procedural strategies like (a) *KWL*, which is commonly used in a lesson to identify 'what I Know, Want of know and what I have Learnt', (b) *question authoring*, like the use of 'What if..' questions, during a lesson or project involving critical thinking and problem solving (CNN, 2003; Fogarty, 1994; Tan, 2007) and review procedures like establishing (c) *clear-unclear windows* (Ellis, 2001; Fogarty, 1994), which may include activities like concept mapping and learning logs writen as a form of self evaluation before, during and/or after a lesson. These strategies require learners to reflect. Many similar strategies are also applicable in experimental science or laboratory practical activities. For example, inquiry-related strategies like (d) *POE* or 'Predict-Observe-Explain' are commonly used before or during an experimental lesson and (e) *recovery strategies* (Ellis, 2001; Fogarty, 1994), for trouble-shooting during problem solving in a practical session. Hence, it is reasonable to state that reflective learning is *not a new idea* in education.

Reflective learning strategies are also metacognitive in nature (Fogarty, 1994). That is, students are encouraged to think about their thinking (Flavell, 1976, 1979). Exposing them to such learning strategies may develop them into metacognitive and reflective learners. However, being reflective specifically requires the learner to not only think about her/his own learning-thinking approaches (metacognitive) but also to make sense of what they have done, are doing and will proceed to do. In other words, they become actively engaged in what Schön (1983) calls in his book, *The Reflective Practitioner*, “reflection-in-action” and “reflection-on-action”. Reflection as a form of thinking is a human activity that cannot be visibly observable. It is therefore necessary to provide ‘proxies’ to indicate that a learner is, or has indeed been, reflecting and not daydreaming or pretending to be thinking.

Students’ Inclination-to-Reflect in Learning School Chemistry

Based on the reflection literature, a model was established by Tan and Goh (2003) to explain how reflective learning could take place in the classroom. A learning-teaching strategy that is commonly illustrated in most reflective learning strategies may be also be applied in the classroom (Figure 1). The reflective learning model and strategy were further developed by Tan (2008) to include the roles of reflective teaching in a classroom lesson (Figure 2) and used in the construction of an instrument to characterise the reflective learning-thinking approaches of secondary three Chemistry students in Singapore. The instrument, known as the Chemistry Learning and Thinking Instrument (or CLTI), includes a list of ten chemistry-related learning tasks. Students’ scores on these tasks would place them either in the ‘high’ group (more inclined-to-reflect compared to the sample’s mean performance) or in the ‘low’ group (less inclined-to-reflect) as illustrated in Figure 5.

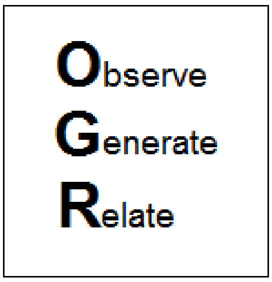


Figure 1. The OGR reflective learning strategy in the classroom

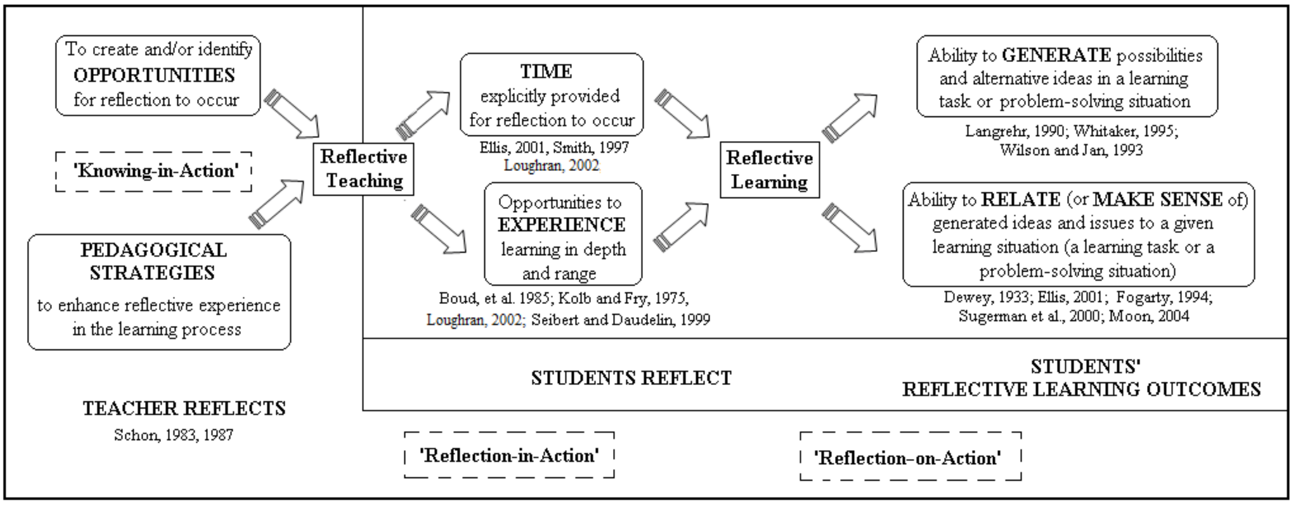


Figure 2. Model to explain reflective teaching and reflective learning in the classroom (Tan, 2008)

The CLTI was not constructed to be psychometric instrument but to be used as an instrument to characterise students' learning-thinking approaches. The items serve to engage students in generating alternative and meaningful solutions or responses to the Chemistry learning tasks. Students are required to respond to all items by writing down their answers in the spaces provided. There are no structured answering prompts in the instrument. That is, *no* boxes or brackets for ticking and *no* lines for writing were provided because students may take these as indications of how many possible answers/alternatives they can generate. Instead, they were only told to write their responses in the blank spaces provided. All questions (with a few exceptions) carry the general instruction for students to "list all possible answers or alternative solutions" to the task. The argument is that the more reflective students should be able to take time to think and link their own experiences with the learning tasks and generate more relevant alternatives or possible solutions. A two-tier scoring scheme was then used to evaluate the students' responses (Table 1).

Tier	If the student is to make a	Score

1	*relevant* or *related* response	one point
2	*correct* or *accurate* response	a maximum of two points

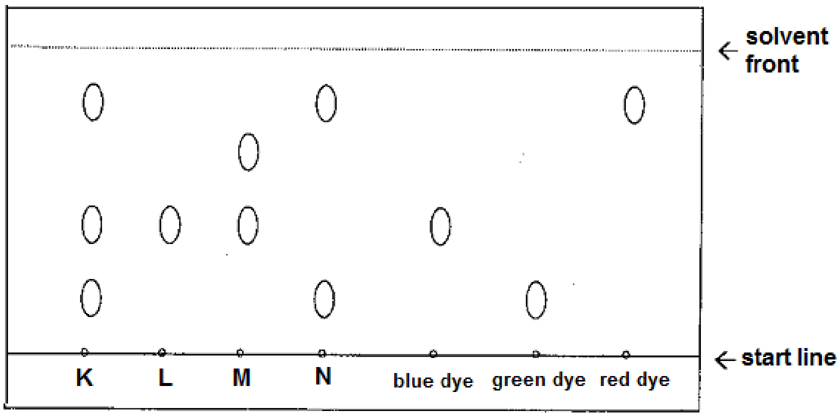
Table 1 Two-tier scoring scheme for students' responses to the items in the CLTI

A *relevant* or *related* response may be partially correct or accurate but is a genuine effort made by the student to answer the question or to respond to the task. A *correct* or *accurate* response[1] refers to a technically and conceptually correct response to the learning task. The total number of relevant or related responses will then become the student's first tier score. The scorer will then re-visit the list of responses, evaluate the correctness or accuracy of each response and award the student the second tier scores for the same responses. The overall performance for that student on that particular learning task would be the sum of the two scores. Thus, the higher the student's overall score, the more inclined she/he is to reflect That is, the student is more inclined to think harder and make links to generate relevant responses.

As an example of how a student's response is scored, consider a student who had listed three correct alternatives or possibilities. She/he would have scored [3 + (3 x 2)] or 9 points. If out of the three only two are correct and the remaining one is either incorrect or inaccurate but is a response related to the task, then she/he would have scored [3 + (2 x 2)] or 7 points. Similarly, if all three responses were incorrect but are relevant to the theme of the task, then the score would be [3 + (3 x 0)] or 3 points. Figure 3 shows some actual examples of such responses from students for an item in the CLTI.

[1] All items and responses are subjected to vetting by a panel of experts. The inter-scorer consistency for the items was found to be at a reasonably value of 0.75)

The following diagram shows a chromatogram obtained using solutions of three single dyes (blue, green and red) and four other solutions (K, L, M and N) that contain one or more dyes.



List all the possible conclusions that can be made from observing the chromatogram obtained above.

Figure 3. Sample Item of the CLTI (Topic on chromatography, Item B9)

Example 1: All generated conclusions are relevant, correct and accurate. (Respondent MD025)

K is a mixture of green dye, blue, dye and red dye.
L is a pure dye containg only blue dye.
M is a ~~[illegible]~~ mixture containing blue dye and a unknown dye.
N is a mixture, containg red dye and green dye.

Scoring: All four points are relevant and correct. Hence the score for this response is [4 + (4 x 2)] = 12 points.

Example 2: Same task but with one incorrect conclusion. (Respondent MD010)

K is made up of red dye and two unknown dyes
L is made up of blue dye
M is made up of blue dye and an unknown dye.
N is made up of green dye and red dye.
Red dye is the most soluble followed by the blue dye and green dye

Scoring: All five conclusions are relevant, but only the first conclusion is incorrect. Hence the score for this response is [5 + (4 x 2)] = 13 points

Example 3: Partially correct conclusions. (Respondent HB003)

K contains dyes of green, blue and red.
L contains ~~dye of blue~~ blue dye.
M contains blue and an unknown dye.
N contains green and red dye.
Both ~~a~~ M and N contains red dye.
K, L and M contains blue dye.
Both K and N contains green dye.
M and N contains two dyes.

Scoring: All eight conclusions are relevant to the task requirement but the fifth conclusion is partially correct (M does not contain the red dye). The sixth and seventh points are repeats of observations made in the earlier points but these are correct conclusions. On a second tier scoring, these three conclusions may be awarded one point (out of two) each.

Hence the score for this response is [8 + (5 x 2) + (3 x 1)] = 21 points

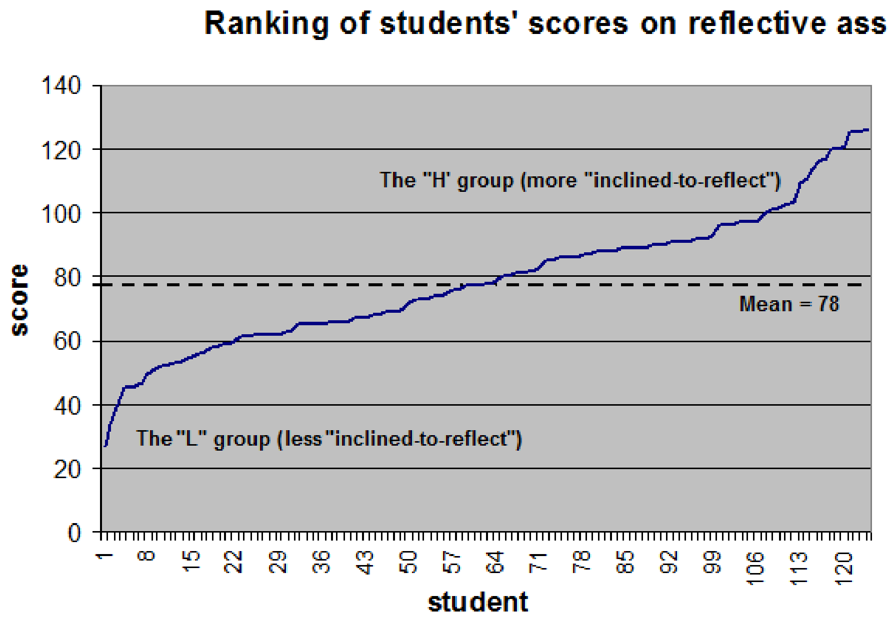
Figure 4. More examples on scoring responses to CLTI items

In Example 3 (Figure 4) , the scorer had also awarded 1 point out of 2 possible points to a partially correct or accurate response. Hence, the scoring on the second tier allows some leeway for the scorer to gauge the quality of a relevant response.

The student's total score for the ten items were then computed and compared to the mean total score of the sample. Students who scored higher than the sample's mean total score would then be identified with an 'H' characteristic for being more inclined-to-reflect compared to the rest. Those with a score lower than the sample's mean total score fall within the group identified with an 'L' characteristic.

Results and Findings

The CLTI was administered as part of a doctoral research on "Students' Ideas in Designing Experimental Set-Ups and their Reflective Learning-Thinking Approaches in School Chemistry" (Tan, 2008). The sample comprises 124 secondary school chemistry students who had completed at least one year of study at upper secondary level (end secondary three or early secondary four). Figure 5 shows the distribution and ranking of the students' scores for the ten-item CLTI survey.



Mean	78.27
Median	78.00
Mode	65.00
Range	105.00
Minimum	27.00
Maximum	132.00
SD	2.25

Figure 5. Distribution and ranking of students' scores for the ten-item CLTI survey.

The results were used in the original study to answer a research question on whether students who are more inclined-to-reflect can design better chemistry experimental set-ups. Good designers of experimental set-ups in the study (those scoring consistently well in design tasks attempted by them in a separate four-task survey form, the Experimental Design Task List (or EDT List) were found to frequently exhibit higher scores on inclination-to-reflect in the CLTI survey (Tan, 2008). The study hence provided some empirical evidences to show that being reflective in their habit of learning may help students perform better in school (at least, in this case, in their ability to design better experimental set-ups).

Discussion and Recommendations

The main research using the CLTI and EDT List has yielded several useful findings, including evidences that 'good designers' of experimental set-ups are more inclined-to-reflect (from their responses to the CLTI items). Due to space constraints, the detailed results will not be reported but two useful recommendations arising from the study are listed below:

(1) Open-ended assessment tasks may be worded to solicit students' reflective responses. Using the two-tier mark scheme, it is possible to grade students over a range of scores, the higher scores being indicative of students' greater inclination-to-reflect.

(2) If students are assessed periodically using reflective assessment items, they may become habitually reflective in their approaches to learning and problem-solving, much like getting them to master the correct (or model) method of solving problems through drills and practices.

There are limitations to a reflective mode of assessment. These include

(1) a large amount of time has to be spent crafting reflective assessment items or re-crafting from typical assessment items, and in scoring students' reflective responses,

(2) ambiguities in students' reflective responses, given that these assessment items have to be open-ended, thus there can be a host of possible answers and responses, and

(3) the readiness of teachers to embrace unfamiliar situations posed by the open-ended nature of the reflective assessment items as well as the infinite and less predictable responses from the students (especially from a mixed ability class).

The limitations are important and should therefore be carefully considered in future efforts relating to assessment of students based on their inclination-to-reflect.

Conclusions

Research on developing objective ways to measure reflectiveness in learning had met with much critical discussions (Kagan, 1965; Krumboltz, 1965). It is difficult, if not impossible, to specifically describe one learner as being more or less reflective than another by a numerical factor. The scores and analyses from the CLTI only serve to describe students as being more or less inclined-to-reflect, compared to the rest (based the sample's mean total). Although this may appear straightforward, it is probably a first step to exploring how a different assessment mode may help our younger learners change their mindsets from wanting to achieve high scores in tests (through mastery and mugging) to one in which they are able to generate alternative relevant ideas to a learning task or problem. Despite the limitations and the apparent straightforwardness of how this part of the study was conducted, the results hold some promises that a more "objective way" to assess students' reflective responses may come true some day. A reflective mode of assessment may be worth the time and effort as it may increase the chances of nurturing a more reflective younger generation of learners who would not rush into making decisions unnecessarily but is able to take time to judge and decide what to do in life in a wiser and more measured way.

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