Investigation of Thai university students’ scientific reasoning abilities

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Abstract. The study aimed to explore scientific reasoning abilities of engineering freshmen in Thailand (N = 680) using 24 multiple-choice questions of Lawson’s Test of Scientific Reasoning (LTSR) and find its relation with high school grade. It was found that male students (N = 442; 73±16%) outperformed female (N = 238; 67±18%) for LTSR scores. Overall, dimension 1 of LTSR about the conservation of mass and volume (80±27%), and dimension 4 about the probabilistic thinking (80±24%) were the highest ability dimensions. In contrast, dimension 6 involving the hypothetical-deductive thinking and reasoning was the lowest ability dimension (50±27%). Moreover, the results revealed no correlation between the LTSR score and high school grade. The findings suggest improving classroom activities which not focus solely on science content knowledge but rather on the scientific reasoning abilities as crucial aspects needed for lifelong learning.

1. Introduction
The scientific reasoning abilities are essential for accomplishment in education, work, and other life circumstances of students in the 21st century [1]. Piaget’s theory of cognitive development, a progressive reorganization of mental processes of people as a result of biological maturation and learning experiences, suggests that adolescents in the formal operational stage are capable to develop their abilities to think about abstract concepts, to logically test hypotheses, to use deductive logic or reasoning from a general principle to specific information, and to systematically plan for the future. In educational implications of the Piaget’s theory, student-centered and discovery-based approaches are significant ways to reinforce scientific reasoning abilities of learners. An inquiry-based approach in science relates to abilities such as identification of question, development hypothetical and counterfactual thinking, isolation of variables, systematic observation and measurement, identifying trends in data using statistical reasoning, construction of models and knowledge communication [2]. Several studies have reported the improvement of students scientific reasoning abilities in inquiry-based instructions including informal learning experiences outside classrooms [3-5]. However, scientific reasoning abilities may be not developed through content-rich instructions, which can gain content knowledge [6].

This research aims to investigate students’ scientific reasoning abilities in Thailand contexts, which there was a rare formal document. The current study addresses two research questions:
(1) What are common features pertaining to scientific reasoning abilities of Thai students participating in this study?
(2) How do their scientific reasoning abilities and high school grade-point-average (HS-GPA) relate?

Research findings will be the guideline to develop Thai students’ reasoning abilities in order to strengthen their success in future careers.
2. Data Collection

2.1 Sample contexts
The participants in this study were first-year engineering students (N = 680) in one public university from the South of Thailand. They were 17-19 years old, and 65% male. Generally, traditional lecture-based instructions including standard lectures, problem-solving, and virtual demonstrations via a computer program or actual demonstrations with simple apparatus are common in high school levels in Thailand. The teacher directs students’ attention to the content topics and students are expected to assimilate information in the class. Some students take science laboratory classes to improve scientific process skills, but most are cookbook laboratories. Many students learn science laboratories in lecture classes through passive teachers’ explanation.

2.2 Research instruments
The participating students were asked to conduct Lawson’s Test of Scientific Reasoning (LTSR) at the beginning of the first semester in the year 2017. The LTSR is an instrument in assessing student scientific reasoning abilities guided by Piagetian tasks [7]. In the year 2000, it was modified from the open-ended version to become a 24-item LTSR in a two-tier multiple-choice version [8]. It asks students’ content knowledge in the first tier and corresponding reasoning to their answer in the second tier. The LTSR assesses students’ scientific reasoning abilities in six dimensions: 1) conservation of mass and volume, 2) proportional thinking, 3) control of variables, 4) probabilistic thinking, 5) correlational thinking, and 6) hypothetico-deductive reasoning. It is a well-known two-tier test for measuring scientific reasoning skills [9-11], and its validity was reported [12-13]. The Thai language translated version of LTSR was carefully checked and validated by a group of Thai physics professors. To assess its internal consistency reliability, we computed the Cronbach’s alpha and obtained 0.82. It was in an acceptable range [14]. In the current study, we have plausibly adopted the individual scheme of scoring the LTSR such that students would receive one credit for one item correctly, so the full score is 24.

In the same week which the students answered the LTSR, we asked them to perform physics placement test (PT), a set of basic physics multiple-choice questions, as well as filling out their high school grade-point-average (HS-GPA). Collected data were analyzed to answer the two research questions.

3. Results and Discussions
Thai participants’ responses to LTSR were divided into 6 dimensions, and categorized by gender as shown in table 1.

| Gender/Dimension | Dim.1 | Dim.2 | Dim.3 | Dim.4 | Dim.5 | Dim.6 | Entire |
|------------------|-------|-------|-------|-------|-------|-------|--------|
| Male (N = 442)   | 84 ± 24 | 72 ± 30 | 72 ± 27 | 81 ± 24 | 77 ± 24 | 51 ± 30 | 73 ± 16 |
| Female (N = 238) | 72 ± 30 | 63 ± 36 | 64 ± 30 | 78 ± 24 | 76 ± 26 | 49 ± 25 | 67 ± 18 |
| Overall (N = 680)| 80 ± 27 | 69 ± 32 | 69 ± 28 | 80 ± 24 | 77 ± 25 | 50 ± 27 | 71 ± 17 |

It revealed a significant difference in mean of LTSR entire scores between male (73±16%) and female (67±18%) participants proved by independent sample t-test at 0.05 significant level (t_{433.694} = 4.369, p < 0.001). Moreover, it was found that the mean score of male students was significantly
greater than that of female students in dimension 1 to 3, but not in dimension 4 to 6. Dimension 4 to 6 relates to higher-order thinking skills namely probabilistic thinking, correlational thinking, hypothetico-deductive reasoning. The skill about hypothetico-deductive reasoning in dimension 6 was also the lowest ability of the samples (50 ± 27%).

Additionally, the students were classified into 3 levels of scientific reasoning abilities as suggested by Lawson and colleagues (2000) [15], as 1) concrete operational reasoner (LTSR < 25%), 2) transitional reasoner (LTSR = 25-58%), and 3) formal operational reasoner (LTSR > 58%). As shown in table 2, our results revealed that all students were in the transitional to the formal operational state indicating the normal cognitive development of young adults. We calculated the Pearson correlation coefficient among LTSR scores, HS-GPA, and physics placement test (PT) scores for each group, and overall. The results disclosed no significant correlation between LTSR scores and HS-GPA, as well as LTSR and PT. Although HS-GPA was from students’ self-report, it had a moderate correlation with PT. Correlation is significant at the 0.01 level. It suggests a reliable HS-GPA information.

Table 2. Correlation coefficients among LTSR score, HS-GPA, PT with corresponding sample size (N), for two clusters and for overall samples

| Variables          | Pearson correlation coefficients |
|--------------------|---------------------------------|
|                    | Overall (N = 680) | Transitional Reasoners (LTSR 25-58%) (N = 138) | Formal Operational Reasoners (LTSR >58%) (N = 542) |
| LTSR and HS-GPA    | -0.04               | 0.18                                           | -0.02                                          |
| LTSR and PT        | 0.04                | 0.14                                           | 0.06                                           |
| HS-GPA and PT      | 0.34**              | 0.36**                                         | 0.34**                                         |

** p < 0.01

The high school grade-point-average (HS-GPA) may reflect several things, including content knowledge, ability to process and retain information, to study, to manage time and so on. This analysis aims to approximately use the HS-GPA variable as an indication of student content knowledge because a common evaluation process to obtain HS-GPA in Thailand mainly relies on levels of student content knowledge. Students with high HS-GPA should have a high body of knowledge for several subjects enrolled in high school levels. A positive correlation between HS-GPA and physics placement test (PT) score was found in this study. It strongly agreed with several works indicating that students who attained high grades in their previous education were more likely to do well in the next course of their study [6, 16].

However, the students, who had high content knowledge, were not necessary to have high scientific reasoning abilities as exposed by no correlation between LTSR and HS-GPA, and between LTSR and PT in this study. Even though we divided the samples into 3 groups (Concrete Operational, Transitional, and Formal Operational reasoners) based on the LTSR score, and only the 2 groups (Transitional and Formal Operational reasoners) were observed for these samples, no correlation between the variables was reported.

Our results are consistent with a study of Bao and colleagues, which reported that physics content knowledge and scientific reasoning skills were independently improved in normal classrooms as gathered data from Chinese and US students [6]. In the current education system, common teaching and assessing knowledge procedures for science subjects emphasize recall of scientific information over a deep understanding of scientific reasoning [17]. Many students try to memorize formulas, problem-solving algorithms, and repeat conveyed messages of their instructors, in order to get a high grade of a course, instead of trying to develop reasoning skills through an inquiry-based approach.
4. Conclusion
In this study, we investigated the scientific reasoning abilities of Thai university students, and find its relationship with high school grade. General features of the participants were such as male students outperformed female for ordinary scientific reasoning abilities. However, both were required to improve higher-order thinking skills, in particular, a skill of hypothetico-deductive reasoning. No correlation between scientific reasoning abilities and high school grade was detected. It implies that common instructions used in high school levels in Thailand cannot activate the scientific reasoning ability. Our findings suggest that scientific reasoning abilities should more emphasize through student-centered and discovery-based instructions, not only content knowledge. This guides science educators and curriculum specialists in improving the pedagogy of science education. Students’ activities, which emphasize more on the integration of scientific reasoning skills and science conceptual learning are significantly required.

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