Fostering Scientific Literacy with Self-evaluation: An intervention Study with Chinese Fifth Graders

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Abstract

Studies on STEM (Science, Technology, Engineering and Mathematics) education reveal that science concept learning is a challenging task for primary school students nowadays. On the other hand, self-evaluation is a promising instructional approach to support science learning with respect to the effectiveness of executive plan, the strategies used, and learning outcomes. Accordingly, we have designed a self-evaluation intervention study to test students' science academic well-being performance by explicit astronomical concepts rubrics presentation. In our study, 103 primary school students were randomly assigned to two self-evaluation conditions. In the experimental classroom, we compared the standard self-evaluation rubric to standard assessment script. After 15 weeks intervention, results showed that the students in the standard self-evaluation rubric conditions show significantly better science learning motivation and scientific capabilities than the standard assessment script group students. Results also indicated that explicit and detailed requirements are essential factors to support astronomical concept learning task by self-evaluation. Finally, the findings support the engagement statements of the Marzano's New Taxonomy of Educational Objectives theory (MNT) in science concept learning field.

Keywords: *Primary school science, astronomical knowledge, concepts evaluation, scientific thinking, learning motivation*

1. Introduction

As one of the earliest natural sciences, astronomy-related knowledge introduces relevant concepts from observing various phenomena (e.g., lunar phases) and extrapolating these to three-dimensionality (3D) to interpret specific representations [1, 2, 3]. It has unique advantages than other STEM (science, technology, engineering, mathematics) disciplines in terms of its multidimensional thinking to support affordance of the universe through space (e.g., at local and large scale) and time. Self-evaluation serves as an effective approach, promoting students' causal reasoning and conceptual change in science learning [4, 5].

'Astronomical concepts' in primary school science learning refer to students' specific representations corresponding to causation and 3D extrapolation through phenomenon observations, which impact preliminary science literacy and scientific thinking formation for further STEM development [4, 6]. Mounting evidence showed that around 30% of primary school students face challenges in astronomy knowledge learning, especially in terms of the difficulties in 'Astronomical concepts' acquisition. Marzano's *New Taxonomy of Educational Objectives (*MNT*)* [7] suggest that sufficient self-evaluation produces a purposed astronomical concept internalisation.

In addition, previous studies mainly used general subject and section as context list (e.g., earth science, lunar phases, etc.) to implement self-evaluation interventions [8, 9]. A few studies have focused on specific typology of astronomy-related knowledge (e.g., the rule of lunar phase, that is, lunar phase changes are formed during the moon's revolution around the Earth and change over time) for self-evaluation intervention. Therefore, the current study integrates self-evaluation of astronomical concepts in science learning environment to test the intervention effectiveness of primary school students' scientific capabilities and motivation outcomes.

2. Methodology

2.1 Participant

This study recruited a total of 103 Chinese primary school students from Chengdu, China. All students were at the Grade 5 level and came from families with low socio-economic incomes. All participants were typical developed students who were not diagnosed with any special education needs, but had poor academic performance in the city standard academic exam. The students were randomly divided into one experimental group (EG) and one control group (CG).

2.2 Measurement

This study employed non-verbal reasoning, working memory, self-evaluation questionnaire, science learning motivation, and science ability test.

2.3 Research Design

As shown in Figure 1, a quasi-experiment with a pre-test, post-test and two-week delayed treatment–control group design was applied. The intervention lasted for 15 weeks; each session was held once per week and inserted into the last 10 minutes of the astronomy lesson. All intervention curriculum designs and measurements were reviewed by two Chinese science learning scholars and two primary school science teachers to ensure the quality of the self-evaluation rubrics given to the students during each astronomy lesson. Consent forms with intervention information were distributed and collected before implementing the intervention. Prior to the intervention, the astronomy teacher also attended a workshop in which the instructors elaborated on how to present instructions to students.

Students received measurements at the following periods: pre-test, post-test and 'delayed post-test' (i.e., two-week after the intervention). It took around one hour to perform the pre-test and around 30 minutes to do the post-test and delayed post-test. During the self-evaluation intervention, EG students received a standard self-evaluation rubric form at the end of 10 minutes for each astronomy lesson. They were then required to report the level of the astronomy principles acquisition by self-evaluation. The students used a rubric containing two categories of information: (1) examples of the application of astronomy concepts (example item: 'The period from new moon to last quarter is approximately 15 days ') and (2) their performance in astronomy principles acquisition (example item: 'The Lunar phases are formed during the movement of Earth around the Sun and the Moon around the earth. ').

When EG performed self-evaluation in astronomy principles acquisition, CG students were required to review what astronomy principles they had learned in that astronomy lesson and finish five exercise items. The EG teacher was asked to complete a checklist to determine whether any students did not submit the self-evaluation rubric report at the end of the lesson. Both CG and EG students received no feedback from the teachers during the last 10 minutes of each lesson. During the intervention, EG students had 100% attendance rate, and all the students submitted the self-evaluation rubric report on time.

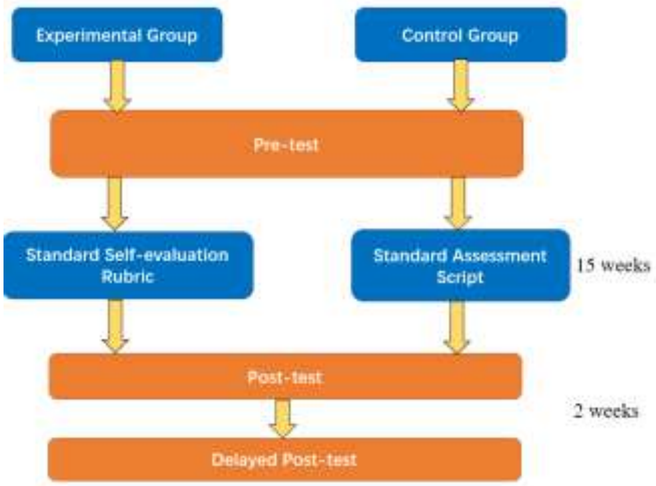

Figure. 1 Research Design

3. Results

As shown in Table 1, all variables' interaction effects between time and group were significant [self-evaluation awareness: $F(2, 96) = 1666.23$, $p < .001$, partial $\eta^2 = .95$; interest: $F(2, 96) = 5.58$, $p < .01$, partial $\eta^2 = .05$; competence: $F(2, 96) = 4.41$, $p < .05$, partial $\eta^2 = .04$; effort: $F(2, 96) = 5.25$, $p < .01$, partial $\eta^2 = .05$; usefulness: $F(2, 96) = 14.09$, $p < .001$, partial $\eta 2 = .13$; pressure: $F(2, 96) = 4.22$, $p < .05$, partial $\eta^2 = .04$; arithmetic thinking: $F(2, 96) = 3.09$, $p < .05$, partial $\eta 2 = .03$; critical thinking: $F(2, 96) = 13.97$, $p < .001$, partial $\eta 2 = .13$; and spatial thinking: $F(2, 96) = 20.91$, $p < .001$, partial $\eta^2 = .17$]. All these results indicated that the EG and CG students showed different performances in the areas of self-evaluation awareness, science learning motivation and scientific ability.

Table 1

Results of Repeated Measures Analysis of Variance

	Time × group intervention effect	
Variables	*F* value	Partial η^2
Self-evaluation Awareness	1666.23^{***}	.95
Science Learning Motivation		
Interest	5.58^{**}	.05
Competence	4.41^{*}	.04
Effort	5.25^{**}	05
Usefulness	14.09^{***}	.13
Pressure	4.22^{*}	.04
Scientific Ability		
Arithmetic Thinking	3.09^{*}	.03
Critical Thinking	13.97^{***}	.13
Spatial Thinking	20.91^{***}	.17

Note. $^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$

4. Discussion

Upon controlling the effect of non-verbal intelligence, working memory, age, gender and teacher's instructional words during intervention, our results showed that the self-evaluation intervention on astronomy concepts learning enhanced poor academic students' performance in the areas of self-evaluation strategy, science learning motivation, mathematics reasoning and spatial thinking. However, the self-evaluation intervention had an insignificant effect on arithmetic thinking development.

After intervention, the level of awareness in applying self-evaluation strategies during astronomy principles learning increased, but only amongst EG students. This result is consistent with previous self-evaluation intervention studies, which demonstrated that students' habit of self-evaluation is enhanced by their actual experience of a self-evaluation design [10]. Through the explicit presentation of a rubric, EG students were required to perform self-evaluation so that they can assess whether they achieved the expected performance stated in the explicit item description. Marzano's MNT theory [7] also suggested that engagement and cognition are essential factors in constructing personal awareness in self-evaluation.

Furthermore, our findings revealed that EG students showed higher levels of science learning motivation than CG students. This is consistent with previous studies, which concluded that self-evaluation enhances learning motivation [11]. Self-determination theory [11] posits that students' personal competence would determine their intrinsic learning motivation. Meanwhile, past studies have demonstrated that self-evaluation intervention can improve students' self-monitoring and self-efficacy on academic knowledge acquisition [12]. Furthermore, higher self-monitoring and self-efficacy positively predict students' self-competence on astronomy knowledge and other science knowledge.

This study provides evidence that a self-evaluation intervention design can improve scientific abilities development, science knowledge learning motivation, and overall awareness of self-evaluation strategy application amongst poor academic learners during knowledge acquisition.

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