

Development of a graphic organiser-based argumentation learning (GOAL) model for improving the self-efficacy and ability to argue of chemistry teacher candidates

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ABSTRACT: The aim of the research reported in this article was to develop a reliable graphic organiser-based argumentation learning (GOAL) model with valid content and constructs. The model can be used to improve the self-efficacy and ability to argue of chemistry teacher candidates. The GOAL model consists of six phases. These are: 1) explaining the objectives and identifying the chemical problems based on the Internet of Things (IoT); 2) modelling graphic organiser-based chemical arguments; 3) investigating chemical problems; 4) presenting chemical arguments; 5) transforming chemical arguments through writing; and 6) examining the understanding of argument-based chemistry and providing feedback. Quality data were obtained through focus group discussion (FGD). The GOAL model quality analysis used average validity scores, the inter-rater correlation coefficient (ICC) and Cronbach's alpha coefficient. The results showed that the GOAL model content and constructs are valid and the model is reliable. Therefore, the GOAL model is of high quality.

INTRODUCTION

The fourth industrial revolution (4IR) will have a large impact on education. Education is important for sustainable development as it provides the means to communicate information, and raise awareness to mobilise communities and the nation into a more sustainable future [1]. Students and graduates are competing in a global society in the era of the 4IR. In order to compete, students and graduates should be a communicator, creative, a critical thinker and collaborator [2]. Students and graduates also must be able to use the Internet of Things (IoT). The ability to argue has become one of the required competencies, because critical thinking skills can develop by argumentation [3]. Argumentation is very important in science and should be taught and studied in science classes as part of scientific inquiry and literacy. This helps to address scientific issues that occur in every aspect of life [4-8].

The importance of the ability to argue in science education has been reported in many studies [6-8]. Some previous research results showed that many teachers and lecturers do not understand the epistemological basics of argumentation, and have limited pedagogical knowledge and skills, especially in designing effective learning activities for students [9-11]. Some of the study results also indicate teacher candidates' lack of ability to argue [12-14]. Hence, students struggle to be confident in their beliefs [15], which can include confidence, adaptability, cognitive capacity, intelligence and capacity to act in stressful situations. Such belief in self is called self-efficacy. Chemistry teacher candidates need self-efficacy belief in their ability to argue. Self-efficacy is important for teacher candidates, because it can influence cognition, motivation, affective processes and ultimately the person's behaviour [16][17].

An initial study of the undergraduate course of chemistry in Mulawarman University showed that the chemistry teacher candidates' argumentation skills were low. The results of the argumentation test showed that only about 33% of chemistry teacher candidates were able to provide claims and evidence, while the other 67% were only able to provide claims. Chemistry teacher candidates also have not been able to provide arguments or contra-arguments against claims [14]. Only 47% of chemistry teacher candidates believe they are always successful in learning organic chemistry, while 53% are sceptical of their ability; sometimes the latter feel stressed and nervous when learning organic chemistry [18].

The lack of self-efficacy and the ability to argue can be overcome with the argument-driven inquiry (ADI) model. The ADI model is widely applied to develop both the ability to argue and the quality of arguments [19-22]. However, in the implementation of the ADI learning model, there are also some disadvantages [23-25], such as being exposed to fewer inquiries resulting in fewer concepts of science being mastered [23-25]. However, the strategies to improve argumentation, pedagogy knowledge of argumentation and self-efficacy of teachers to teach science through argumentation is still limited [17]. The Internet of Things (IoT) has become one of the fundamental needs in education in the fourth industrial revolution. Therefore, it is necessary to develop a chemistry learning model that can integrate a graphic organiser and IoT with self-efficacy and the ability to argue. This innovation is expected to improve the self-efficacy and ability to argue of chemistry teacher candidates. Hence, the need to develop the graphic organiser-based argumentation learning (GOAL) model can improve self-efficacy and the ability to argue. The main objective of this study was to produce a valid GOAL model for improving self-efficacy and the ability to argue of chemistry teacher candidates.

RESEARCH METHODS

The development of the GOAL model adapted the Wademan model of research development as shown in Figure 1.

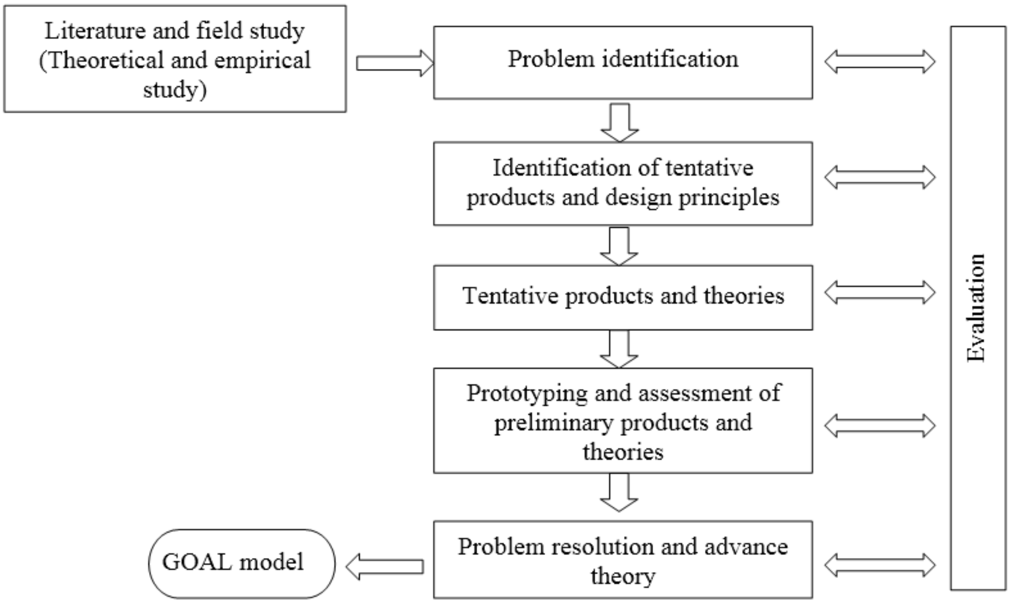

Figure 1: Development of the GOAL model using the Wademan model adaptation [26][27].

The subjects of this research were chemistry teacher candidates in Mulawarman University who had taken an organic chemistry course. The objective of this research and development (R&D) study was to produce a quality GOAL model that has valid content, constructs and is reliable. The aim was to improve the self-efficacy and ability to argue of chemistry teacher candidates. The main product was a GOAL model book. The GOAL model book includes:

a) introduction;
b) flow of the model;
c) model characteristics;
d) model implementation;
e) references.

It was necessary to assess the quality in terms of content validity, construct validity and reliability of the GOAL model. This involved supporting instruments consisting of:

1) validation sheet of GOAL model content;
2) validation sheet of GOAL model constructs.

These instruments have been declared valid and reliable [28]. The GOAL model was validated by four experts in a focus group discussion (FGD). The FGD was a small group discussion in which participants responded to a series of questions focused on a single topic [29]. Experts in the FGD consisted of a professor of science education, a professor of chemistry, a doctor of chemistry education and a doctor of chemistry. The FGD lasted two hours. Three weeks before the FGD, the experts were given GOAL model books and GOAL model validation sheets. The GOAL model validation sheets were filled by the experts who reviewed and assessed the learning model developed by the researchers. The GOAL model validation sheets were used to obtain validity and reliability data of the GOAL model. The validity of the GOAL model was judged by the content and constructs validity. Product validity of the model is divided into content validity and constructs validity [26-29]. Content validity is concerned with there being a need for the model and its design being based on state-of-the-art knowledge [26-29]. Constructs validity is concerned with the model being logically designed [26-29]. The FGD results served as a reference for revising the GOAL model.

The validity of GOAL model was determined by reference to the assessed average validity score. Criteria were [28][29]:

- $3.25 <$ very valid ≤ 4.00
- $2.50 <$ valid ≤ 3.25

- 1.75 < less valid ≤ 2.50
- 1.00 ≤ invalid ≤ 1.75

Further analysis to determine the quality of the GOAL model in terms of validity and reliability used single measure inter-rater correlation coefficient (ICC) and Cronbach's alpha (α). The validity and reliability of the GOAL model was determined using the validity formula [30][31]:

$$r_\alpha = [(\text{mean square error - mean square residual})/(\text{mean square} + (k\text{-}1) * \text{mean square residual})] \quad (1)$$

and

Cronbach's alpha:

$$\alpha = k\, r_\alpha / [1+ (k\text{-}1)\, r_\alpha] \quad (2)$$

The GOAL model was valid if r_α > r table and invalid if r_α ≤ r table. The GOAL model quality analysis was further strengthened using qualitative data obtained during the FGD.

RESULTS AND DISCUSSION

The GOAL model has been validated by four experts using a FGD. Experts in the FGD consisted of a professor of science education, a professor of chemistry, a doctor of chemistry education and a doctor of chemistry. The GOAL model quality assessment results are presented in Table 1.

Table 1: Results of the GOAL model quality assessment.

Component	Validity and reliability of GOAL model				
Content validity	Average validity score	r_α	Validity	α	Reliability
1. Rationale for GOAL model development	4.00	1.00	Valid	1.00	Reliable
2. State-of-the-art knowledge	3.82	0.67	Valid	0.53	Reliable
3. Follow-up model development results	4.00	1.00	Valid	1.00	Reliable
Constructs validity					
1. GOAL model rationale	4.00	1.00	Valid	1.00	Reliable
2. Theoretical and empirical support	3.78	1.00	Valid	1.00	Reliable
3. Syntax	3.70	1.00	Valid	1.00	Reliable
4. Social system	3.89	1.00	Valid	1.00	Reliable
5. Reaction principle	4.00	1.00	Valid	1.00	Reliable
6. Support system	4.00	1.00	Valid	1.00	Reliable
7. Instructional impact and accompanist impact	4.00	1.00	Valid	1.00	Reliable

Table 1 shows the validity of content and reliability of the GOAL model and includes: 1) rationale for GOAL model development; 2) state-of-the-art knowledge; and 3) follow-up model development results. These had average validation scores of 4.00, 3.82, and 4.00, respectively and very high validity criteria with r_α = 1.00, 0.67, and 1.00; these were greater than the r table value, so each component was declared valid. Each component was declared reliable with α = 1.00, 0.53 and 1.00.

Table 1 shows the validity of constructs and reliability of the GOAL model and includes: 1) GOAL model rationale; 2) theoretical and empirical support; 3) syntax; 4) social system; 5) reaction principle; 6) support system; and 7) instructional impact and accompanist impact. These had average validation scores of 4.00; 3.78; 3.70; 3.89; 4.00; 4.00; and 4.00, respectively and very high validity criteria with r_α = 1.00 for all; these were greater than the r table value, so each component was declared valid. Each component was declared reliable with an α = 1.00 for all components.

The results of the statistical test were reinforced by qualitative data analysis. Qualitative data analysis revealed three themes for the validity of content and seven themes for the validity of constructs (see Table 1). Table 2 presents the summary of qualitative data by validators during the FGD for the GOAL model quality assessment.

Table 2: Summary of qualitative data for the GOAL model quality assessment.

Qualitative data from three validators	Quality component of GOAL model
The validators stated: *The rationale for the GOAL model development is valid.*	Rational development
The validators stated: *The state of the art of knowledge for the GOAL model is valid. The GOAL model is novel and improves on the weaknesses of the argument-driven inquiry (ADI) model based on recommendations of researchers.*	State-of-the-art knowledge

Qualitative data from three validators	Quality component of GOAL model
The validators also stated: *Follow-up on GOAL model development is valid. The developed model can be followed up by further research, by seeking coherent phase activities in the syntax. The developed model can be applied to learning.*	Follow-up of model development results
In the FGD, the validators judged: *The GOAL model rationale is valid. There is a correspondence between the rationale for developing a learning model and current needs.*	GOAL model rationale
The validators judged: *The Goals' theoretical and empirical support is valid. There is a match between the GOAL model and learning theories and their empirical support.*	Theoretical and empirical support
The validators also rated that: *The syntax of the GOAL model is valid. The phases in the syntax show the sequence of activities to achieve the learning objectives of the ability to argue and self-efficacy*.	Syntax
The validators stated: *The social system that describes the role of students and lecturers, interaction between students, between lecturers and students, and expected targets are valid. The existence of a pattern in the relationship between lecturer and student shows that the role of the student is more dominant, and collaborative.*	Social system
The validators also stated: *Validators believe that the principle of a logical reaction relating to how the lecturer notices and treats the student, has been stated and described in the model book, so that it is declared to be valid*.	Reaction principle
The validators opined: *The learning model support systems consisting of learning tools and learning resources for implementing the GOAL model have been stated logically in the model book, so it is valid.*	Support system
The validators also judged: *The instructional impact and accompanist impact of the GOAL model was declared valid. The instructional impact is an achievement measure of the basic competencies of the GOAL model and the accompanist impact is acquired, because the environment created by the model has been clearly and logically stated in the GOAL model book.*	Instructional impact and accompanist impact

The three components of content validity of the GOAL model are considered valid. Model content validity can be viewed as novel and state of the art. The novelty of the GOAL model, compared to the ADI model, is in improving the ability to argue and self-efficacy. This is so for phase 2 of the chemistry teacher candidates' activities using the GOAL model, i.e. modelling graphical organiser-based chemical arguments (see Table 3). This phase is designed for chemistry teacher candidates to better understand how to argue. Chemistry teacher candidates imitate the argumentative action of lecturers through the presentation of graphic organisers. This is designed to assist chemistry teacher candidates in argumentation; self-efficacy grows through vicarious experiences. It is hoped that by imitating arguing, chemistry teacher candidates will learn to successfully engage in epistemic practice, such as elaboration, reflection and reasoning as evidence of their participation in the construction of scientific arguments and evaluation activities [7][32].

Mason reveals that argumentation is a form of discourse the needs of which are tailored to students and explicitly taught through appropriate instruction, structured tasks and modelling [33]. The modelling of an argument provides an opportunity for chemistry teacher candidates to witness the lecturer's experience and visualise themselves in similar situations. The construct validity of the GOAL model is determined by the consistency between phases in the model syntax, the consistency between the model components, and the consistency between the model and the underlying theory. The consistency between phases in the syntax can be traced to the rational order of phases to form the model syntax. Consistency between model components is based on the interrelation between the rational model, model syntax, social system, reaction principle and support system, as well as instructional impact and accompanist impact. There is consistency between the model and learning theories, i.e. cognitive theory, cognitive social theory, information processing theory and constructivist theory.

Table 3: The chemistry teacher candidates' activities using the GOAL model.

Activities of chemistry teacher candidates
Phase 1: Explaining the objectives and identifying chemical problems based on the Internet of Things (IoT).
1. Chemistry teacher candidates pay attention to the phenomenon of chemical problems based on the Internet of Things (IoT). 2. Chemistry teacher candidates identify, analyse and answer problems, so students can relate their experience to what they will learn and improve their knowledge. 3. Chemistry teacher candidates are motivated toward self-efficacy beliefs by successfully completing tasks and explaining the purpose of the activities undertaken. 4. Chemistry teacher candidates pay attention to directed learning and the success criteria submitted by the lecturer.
Phase 2: Modelling graphical organiser-based chemical arguments.
1. The lecturer uses the IoT (Chem Office) to present the main topic so that chemistry teacher candidates should listen, pay attention and respond. 2. Chemistry teacher candidates mimic the argumentative action of the lecturer and self-efficacy beliefs grow through vicarious experiences.

Activities of chemistry teacher candidates
3. Chemistry teacher candidates practise developing arguments on how to file a claim, i.e. problem formulation; containing evidence or data to support the claim; using the concept or principles of chemistry to explain why the data used are relevant and important to the claim; adding backing material, i.e. information about assumptions that can support data, as well as qualifications - information that explains the conditions when the claim is true.
Phase 3: Investigating chemical problems
1. Chemistry teacher candidates work in collaborative groups (3-4 persons) to conduct investigative activities to formulate arguments and answer set tasks. 2. Prepare in groups, IoT-based media to be presented, maintained and shared with other groups. 3. Chemistry teacher candidates strive to find various IoT-based sources that can support their arguments.
Phase 4: Presenting chemical arguments
1. Chemistry teacher candidates communicate the results of their investigations for understanding arguing skills and building self-efficacy. 2. Each group is given a chance to pass on its argument for the other group to critique the claims and arguments. 3. Chemistry teacher candidates evaluate the validity of any claim; support their agreement or disagreement with rational justification accompanied by credible evidence.
Phase 5: Transforming chemical arguments through writing
1. Chemistry teacher candidates develop written arguments from the results of investigative activities. 2. Chemistry teacher candidates are challenged to evaluate the validity of claims using their knowledge.
Phase 6: Examining understanding of argument-based chemistry and providing feedback
1. Chemistry teacher candidates do an advanced task. 2. Chemistry teacher candidates together with lecturers validate the answers to questions. 3. Listen and pay attention to the feedback given to increase self-efficacy.

The consistency between phases in the model syntax has been demonstrated for the GOAL model. Table 3 shows the six phases of the GOAL model and consists of: 1) explaining the objectives and identifying the chemical problems based on the IoT; 2) modelling graphical organiser-based chemical arguments; 3) investigating chemical problems; 4) presenting chemical arguments; 5) transforming chemical arguments through writing; and 6) examining the understanding of argument-based chemistry and providing feedback. The six phases are interrelated.

The FGD findings showed that the GOAL model is valid in content and construct and reliable. The model has several characteristics, i.e. satisfies the needs, is state of the art, has a strong theoretical and empirical foundation, and there is consistency among the components of the model [27]. The results showed that the product (model, device and learning) can be used to improve learning outcomes [34-37].

The GOAL model is state of the art and meets needs implying that it is valid in content. Consistency between model sections and the consistency between the model and the underlying theories suggests that the GOAL model's construct is valid. The learning model has focused on designing the learning environment in accordance with learning theory, as well as explaining the learning process and how the learning environment was created. Based on the GOAL model quality assessment, the GOAL model is valid in content and constructs, and is reliable, so is qualified to be used as a guide in planning chemistry teaching, students' development of self-efficacy and the ability to argue.

CONCLUSIONS

The GOAL model consists of six phases. These are 1) explaining the objectives and identifying chemical problems based on the IoT; 2) modelling graphical organiser-based chemical arguments; 3) investigating chemical problems; 4) presenting chemical arguments; 5) transforming chemical arguments through writing; and 6) examining the understanding of argument-based chemistry and providing feedback.

The results show that the GOAL model has content and constructs validity, and is reliable. Hence, the GOAL model is of high quality. The implication of this research is that the GOAL model can be used to improve the self-efficacy and ability to argue of chemistry teacher candidates. Further research could be conducted to continue testing the practicality and effectiveness of the GOAL model.

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