

Designing a competencies framework for STEM teaching for pre-teachers of chemistry in the University of Education for meeting the new demands of current teacher training

Hoang Thi Chien

Thai Nguyên University of Education
Email: hoangchien-khoahoa@dhsptn.edu.vn

Received: 27/5/2019

Reviewed: 3/6/2019

Revised: 7/6/2019

Accepted: 12/6/2019

Released: 21/6/2019

DOI:

<https://doi.org/10.25073/0866-773X/306>

The STEM education teaching approach (STEM teaching) has been one of the important orientations of the Vietnamese general education program. However, thus far there has been no competency framework for STEM teaching in our country. A competency framework for STEM teaching would include two important things. With this framework, learners would have complete control when setting up their plan, finding information, defining the learning content methodologies and providing multi-subject knowledge at the beginning of a procedure. Furthermore, it can be orientated to evaluate the expression level of each student. This paper presents the process of designing a competency framework for a STEM teaching and suggests the ways to use this framework at the University of Education.

Keywords: Competency framework; STEM teaching; University of Education; Chemistry pre-teacher.

1. Introduction

STEM educating is one of the most essential educational trends in many countries in the world and is paid suitable attention under the period of educational reforming in Vietnam. In the new general education curriculum being implemented in 2019, STEM education is defined as a teaching method via Science, Technology, Engineering and Mathematics, which is an integrated approach to education, interdisciplinary from two or more fields among Science, Technology, Engineering and Mathematics, in which the content is linked to reality, teaching method is action-oriented [1].

In the new general education curriculum, subjects in the natural scientific fields (Physics, Chemistry, Biology) are STEM's subjects. The content of these subjects are supposed to ensure the development of knowledge and practical skills on the basis of common capabilities and learning capacity, meeting the requirements of orientation in specific occupations, helping students decide on their careers based on their hobbies and abilities. [2, p. 19]

However, it is a fact that not all teachers and educators understand the true meaning of STEM and STEM education. Now, in the practice of teaching, being trained to teach one subject only, STEM-oriented teaching capacity of high school teachers is, consequently, limited, not only in terms of knowledge but also the method to organize

a teaching process. The Ministry of Education and Training has actively implemented activities to form and develop STEM education-oriented teaching capacity for upper secondary teachers by guiding the implementation of integrated teaching, theme-based teaching, developing plans for each subject in the orientation of improving the capacity and qualities of learners in implementing the task plan for the school year, designing and organizing teaching activities in association with production and business, etc. [4].

There is no STEM-oriented framework of competency for teachers and pre-teachers, in general, and Chemistry ones, in particular. The research and development of the framework of competency mentioned above is of much theoretical and practical significance. It can support the measurement and evaluation of STEM-oriented teaching competencies that are relevant to the domestic context, while providing the right direction in fostering and developing this capacity for Chemistry teachers and pre-teachers.

2. Methods

2.1. An overview of STEM education and STEM-oriented teaching competency

2.1.1. An overview of STEM education

STEM stands for Science, Technology, Engineering, and Math. The term STEM is often used in the context of education and professional. In the context of education, STEM is synonymous

with STEM education, which is understood as using scientific and mathematical evidence to explore the natural and human world, enhance and resolve issues of life. [5]

From the perspective of education and in the Vietnamese context, STEM education, on the one hand, fulfills the educational objectives stated in the general education curriculum. On the other hand, STEM education aims at developing typical features of STEM subjects, thereby improving core competencies and orienting career students [3, p. 7].

According to Assoc. Nguyen Xuan Thanh (2017): STEM educating is an integrated education approach (Science - Technology - Engineering - Math), not a subject, in which lessons are developed on the theme of STEM, integrating science and math knowledge with problems in technology, engineering and reality. Thus, students are enabled to learn the scientific knowledge, and how to apply it in practice. In each STEM-themed lesson, students are given a problematic situation that is in relation to the knowledge they are going to study during the lesson. In order to solve that problem, students must research and study the subject matter related to that problem (through textbooks, learning materials, laboratory equipment, technology equipment) and use them to solve the problem. As a result, STEM education will help to achieve the goal of developing the capacity and quality of students to meet new requirements. Students will easily acquire the knowledge associated with their applications in technology and engineering; use learned knowledge to innovate in science, technology and engineering. [6]

Each STEM-themed lesson is geared toward an application product that students need to complete but it should not be identified with manufacturing product. It is important for students to apply scientific knowledge to “design” and then “execute”. Thus, new students develop the necessary skills of an “engineer” rather than a “craftsman”.

2.1.2. An overview of STEM-oriented teaching competency

The concept of STEM-oriented teaching competency has not been defined in the standards of college-level teachers.

In STEM educating as well as other positive teaching methods, the teacher acts as the organizer, examiner, orienting man; students actively gain knowledge and apply it in solving practical problems. STEM-oriented teaching has been guided by the Ministry of Education and Training for many years through the teaching of the topic “Integrating, Interdisciplinary”, planning the lesson with STEM-oriented theme for lessons with practical contents. Accordingly, teachers, teams / groups are assigned the right to actively build the topic of integrated and

interdisciplinary teaching associated with practical issues. There are many STEM-oriented teaching subjects in the natural sciences that are developed and implemented effectively by teachers [6].

The STEM-oriented instructional process used in a chapter or a lesson in teaching science is described in the following steps: Problem introduction - Exploration - Explanation - Extension - Assessment, following the model of 5E (Engagement - Exploration - Explanation - Elaboration - Evaluation) [9]. The main idea of STEM-oriented teaching is based on the connection of knowledge in different fields: science, technology, engineering and mathematics, as well as practical situations. Hence, the scientific basis of STEM-oriented teaching are of integrative teaching theory, capacity-driven instruction, and it has the intrinsic nature of integrated teaching and capacity-oriented instruction. The characteristics of STEM-oriented teaching are: Integrity, Design-ness and Comprehensiveness [3, p. 11].

Based on the above analysis, in combination with the definition “Capacity is a personal characteristic which is formed, developed by the innate abilities and the process of learning, training, allowing people to mobilize aggregate knowledge, skills and other personal attributes such as excitement, beliefs, wills, etc, successfully implement a certain type of activity, achieving desired results under specific conditions [2, p.36], we believe that the STEM-oriented teaching competency is the ability of individuals’ to combine integrative teaching and targeted instruction when teaching a subject connected to practice.

2.2. The proposed structure of STEM-oriented teaching framework of competency for Chemistry pre-teachers

2.2.1. Process of capacity building

Step 1- Researching and identifying the bases for establishing the framework: We have studied STEM-related materials, integrated teaching capabilities, and teaching capabilities of Chemistry teachers with a view to build the structure of the STEM-oriented teaching framework of competency in accordance with the realities of education in the new period. Here is the detailed list of the documents:

- 1) General education curriculum;
- 2) Provisions on professional standards of high school teachers;
- 3) Standardized output of pedagogical students in Chemistry under the curricula of Universities of Education;
- 4) The objectives and tasks of Chemistry in general schools;
- 5) Objectives and structure of the module

“Methods of teaching Chemistry in high schools” in pedagogical schools.

Step 2 - Identifying component competencies: Proposing component competencies,

Step 3 - Defining the criteria for component competencies: Describing the manifestations of each competency, developing criteria for each component competency, proposing a draft of the framework of competency that includes component competencies and criteria attached.

Step 4 - Describing in detail the manifestations of the criteria in the framework by level: To facilitate the design of the assessment tools for students, we propose a system of criteria describing the competency level corresponds to the performance.

Step 5 - Reviewing, adjusting, supplementing and completing the framework of competency: The table of criteria is also reviewed and adjusted after being consulted by experts.

2.2.2. The structure of STEM-oriented teaching competencies

Basing on [3] and [8], we have defined the structure of STEM-oriented teaching competency, which includes the following components:

1) The ability to build up STEM-oriented educational topics: It is the ability of students to select the specific content of the subject, rearrange it, make the connection between that content with the products in the real life, analyze their use, indicate the relevant knowledge in the STEM fields, form a topic.

2) The ability to design and organize STEM teaching activities: It is the ability of the students to define the purpose of the topic, design learning activities that are appropriate for the target, design effective learning activities which can apply information technology.

3) The ability to test and evaluate in STEM teaching: It is the ability of students to design and use effective STEM knowledge and assessment tools.

Based on the definition of the STEM-oriented teaching and the characteristics of the curriculum of the Bachelor of Chemistry, a framework of STEM teaching competency has been built as following:

Table 1: Description of structure of STEM-oriented teaching competency

Component competency	Criteria
1) The ability to build up STEM-oriented educational topics	Criterion 1: Selecting the specific content of the subject
	Criterion 2: Linking between the content with products which are important and feasible in the real life
	Criterion 3: Analyzing the application and use of the products in the real life
	Criterion 4: Forming a topic
2) The ability to design and organize STEM teaching activities	Criterion 5: Identifying the target of the topic
	Criterion 6: Designing learning activities and tasks; assigning tasks
	Criterion 7: Effectively executing the activities
	Criterion 8: Applying information technology
3) The ability to test and evaluate in STEM teaching	Criterion 9: Designing tools to assess knowledge and skills belonging to STEM
	Criterion 10: Utilizing the assessing tools

From the STEM-oriented framework of teaching competency, we propose four basic levels from low to high capacity as follows:

Level 1: Students' competency is low; it needs to be formed.

Level 2: Students' competency is at medium level (initially formed); it needs to be fostered.

Level 3: Students' competency is at a good level (formed); it needs to be fostered to develop.

Level 4: Students' competency is at a high level (formed and developed); it needs to be maintained.

Based on the descriptions of these basic levels, we describe in detail the level of manifestation of competencies through the following criteria:

Table 2. Detailed description of STEM-oriented framework of teaching competencies of Chemistry pre-teachers

Criteria	Level			
	4	3	2	1
1) The ability to build up STEM-oriented educational topics				
Criterion 1: Selecting the specific content of the subject	Analyze, identify the scope of contents of the chapter/unit, point out the relevant practical issues.	Analyze the characteristics, but not the scope of the contents of the chapter/unit, point out the relevant practical problems.	Analyze the characteristics of the content of the chapter/unit, initially recognize the relevant practical issues.	The content of the chapter/unit has not been analyzed, cannot address the relevant practical issues.
Criterion 2: Linking between the content with products which are important and feasible in the real life	Fully describe chemical products in terms of form, composition, properties, uses, production, etc. in practice.	Not fully describe the chemical products in terms of form, composition, properties, uses, production, etc. in practice	Describe the chemical products in terms of form, composition, uses, production, etc. according to the textbook.	Cannot describe the chemical products in terms of form, composition, properties, uses, production, etc. in practice.
Criterion 3: Analyzing the application and use of the products in the real life	Analyze in detail the applications and benefits and disadvantages of the use and production of products in life.	Inadequately analyze in detail the applications, benefits and disadvantages of the use and production of products in life.	Analyze applications, benefits and disadvantages of the use and production of products in life but not detailed and complete.	State without analyzing the applications, benefits and disadvantages of the use and production of products in the life.
Criterion 4: Forming a topic	The topic is formed by re-arranging the contents of the program, the name and the content are in accordance with practical issues.	The topic is formed from the available lessons, naming and defining content that is in accordance with the practical issues.	The topic is formed from the available lessons, with re-arrangement of the name and content but not suitable with practical issues.	The topic is formed from the available lessons, without re-arrangement of the name and content to suit the practical issues.
2) The ability to design and organize STEM teaching activities				
Criterion 5: Identifying the objectives of the topic	The objectives are clearly defined, full of components, using measurable action verbs.	The objectives are clearly defined, full of components, but sometimes use of cognitive verbs which are difficult to measure.	The objectives are quite clearly defined, full of components, use too many cognitive words that are difficult to measure.	The objectives are not clearly defined, not full of components, not use measurable action verbs.
Criterion 6: Designing learning activities and tasks; assigning tasks	Select and design learning activities which are suitable with the objectives; describe the objectives, content, techniques and products in details.	Design learning activities in the sequences described in textbook, suitable with objectives; describe the objectives, content, techniques and products in details.	Design learning activities in the sequences described in textbook, suitable with objectives; not describe the objectives, content, techniques and products in details.	Not design learning activities in the sequence described in textbook which includes: objectives, content, techniques and products.
Criterion 7: Effectively executing the activities	Organize learning activities for students by assigning tasks, encourage and help students to operate, answer and conclude. Students complete the learning products by themselves.	Organize learning activities for students by assigning tasks, encourage and help students to operate, answer and conclude. Students are supported to complete the learning products.	Organize learning activities for students by assigning tasks, encourage and help students to operate, answer and conclude. Students are guided to complete the learning products.	Not organize learning activities for students by assigning tasks; teacher talking time is too much, students do not work to conclude and cannot complete the learning products.
Criterion 8: Applying information technology	Apply information technology in designing lesson plans and effectively delivering the lessons.	Apply information technology in designing lesson plans, but not effectively deliver the lessons.	Apply information technology in planning lessons and teaching.	Not apply information technology in planning lessons and teaching.
3) The ability to test and evaluate in STEM teaching				
Criterion 9: Designing tools to assess knowledge and skills belonging to STEM	Design reasonable and logical assessing tools (tests) to evaluate STEM knowledge and skills.	Design reasonable but not logical assessing tools (tests) to evaluate STEM knowledge and skills.	Design assessing tools (tests) to evaluate STEM knowledge and skills but they are not reasonable and logical.	Not distinguish and design assessing tools (tests) to evaluate STEM knowledge and skills.
Criterion 10: Utilizing the assessing tools	Use the assessing tools effectively.	Use the assessing tools.	Use the assessing tools ineffectively.	Unable to use assessing tools.

2.2.3. Use the STEM-oriented framework of teaching competency in the professional training for Chemistry pre-teachers

The framework of teaching competency plays an important role in the development of STEM-oriented teaching capacity of Chemistry pre-teachers.

1) The framework plays a pivotal role in developing STEM themes for students. With this framework, students are provided with clear, detailed information about the requirements for STEM-oriented teaching competencies. As a consequence, learners will be able to actively plan, seek information, determine content, methods and supplement knowledge at the beginning of the training process. On the other hand, learners will be more responsible with their studies by recognizing their own strengths and weaknesses when comparing and contrasting the results obtained at the different milestones which are differentiated by the criteria described in the framework of competency. At the same time, lecturers can also base on this framework to select the content and learning methods that help students train the capacity most effectively.

2) The framework of competency is the basis for lecturers to develop competency assessment tools for students. For effective training, assessment should be done regularly during the training process. Based on the competency framework, trainers can design assessment tools (trainers-trainees, peer review) and self-assessments such as checklists, peer assessing forms, score, rubrics, and so on. With detailed descriptions of the levels

to be achieved, the learner is always watching the progress of himself, his partner, his group, and the lecturer also has accurate information which helps to strictly control the progress of students for timely measures.

Lecturers can use the above detailed description of the levels of STEM-oriented teaching competencies for Chemistry pre-teachers to assess their level of performance. It is possible to calculate the average of each student's observation, or of each student's expression, and compare it with the proposed four-grade table. Hence, lecturers can assess the STEM-oriented teaching competency of each student or the whole class. If the observation point or grade point average is close to level 1, the corresponding student's capacity is low, which should be improved. If the average grade point is above 3, the student has a high level of competence, which should be maintained.

This checklist can be used regularly for lecturers and students to evaluate weekly or monthly. By comparing the results of the cross-sectional checklist, lecturers and students can evaluate the development of competencies in the teaching and learning process.

3. Summary

After the process of constructing and using STEM-oriented teaching framework of competency in the module of Teaching Chemistry Methodology at the Faculty of Chemistry, Thai Nguyen University of Education in 2016 - 2017, 2017 - 2018, we have achieved positive results. The framework has helped lecturers to identify the objectives for students in the

Example: The checklist examining the STEM-oriented teaching competency of Chemistry pre-teachers

Convention: Level 1: 1 point; Level 2: 2 points; Level 3: 3 points; Level 4: 4 points.

Group:..... Class:.....University of Education:.....

No.	Expression of competency	Students' ordinal number											
		1	2	3	4	5	6	7	8	9	10	...	
1	Select the specific content of the subject												
2	Connect with products that have important applications in practice												
3	Analyze the application and use of products in life												
4	Form the topic												
5	Determine the objectives of the topic												
6	Design learning activities and tasks												
7	Effectively organize learning activities												
8	Apply information technology												
9	Design assessing tools to evaluate STEM knowledge and skills												
10	Utilize assessing tools												
Total results													

module, thereby developing the content of teaching and choosing more appropriate method of teaching. At the same time, more opportunities have been created for students to participate and evaluate the

process, which, consequently, helps them to know what to do and to improve for the best results. This approach is perfectly suited to the requirements of learner-developing-oriented teaching method.

References

- [1] http://sgddt.tiengiang.gov.vn/75-nam-thanh-lap-oi-tntp-hcm/-/asset_publisher/pnNeqFOSeYQY/content/Doc-String-in-chong-trinh-giao-duc-pho-thong-moi, accessed on 10/Oct/2018
- [2] Ministry of Education and Training, Education Curriculum - General Program, 2017.
- [3] Le Xuan Quang, *Teaching Technology in the orientation of STEM teaching*, Ph.D thesis, Hanoi University of Education, 2017.
- [4] Ministry of Education and Training, *Official Letter No. 4612 / MOET-SSE, dated 03/10/2017*, Guiding the implementation of the current general education curriculum in the orientation of capacity and quality development for students starting at the academic years 2017-2018.
- [5] [http // www.britishcouncil.vn / sites / default / files / tong_hop_link_tai_lieu_tap_huan_stem_thang_8_0.pdf](http://www.britishcouncil.vn/sites/default/files/tong_hop_link_tai_lieu_tap_huan_stem_thang_8_0.pdf) / Training on STEM-oriented teaching methods - accessed on 15/Oct/2018
- [6] <http://www.moet.gov.vn/tintuc/Pages/tin-tong-hop.aspx?ItemID=4683/> STEM Education in Schools: Not Just Theory - 6/May/2017.
- [7] Ministry of Education and Training, OL 1891 /MOET-UE 5/May/2017: Promoting and developing STEM education (Science, Technology, Engineering and Mathematics), applying interdisciplinary knowledge to solve problems in life and production.
- [8] Assoc. Nguyen Xuan Thanh, Organizing teaching procedure in association with production and business in the general education curriculum, Core Teacher Training Lecture - Dec/2017.
- [9] Nguyen Thanh Hai, <https://hocvienkhampha.edu.vn/mo-hinh-day-hoc-5e-trong-giao-duc-stem>, accessed on 15/Oct/2018
- [10] Boston Children Museum, *STEM Sprouts Teaching Guide*, 2013

XÂY DỰNG KHUNG NĂNG LỰC DẠY HỌC STEM CHO SINH VIÊN SƯ PHẠM HÓA HỌC ĐÁP ỨNG YÊU CẦU ĐỔI MỚI ĐÀO TẠO GIÁO VIÊN HIỆN NAY

Hoàng Thị Chiên

Đại học Sư phạm Thái Nguyên
Email: hoangchien-khoahoa@dhsptn.edu.vn

Ngày nhận bài: 27/5/2019
Ngày gửi phản biện: 3/6/2019
Ngày tác giả sửa: 7/6/2019
Ngày duyệt đăng: 12/6/2019
Ngày phát hành: 21/6/2019

DOI:
<https://doi.org/10.25073/0866-773X/306>

Tóm tắt: Dạy học theo quan điểm giáo dục STEM (dạy học STEM) là một trong những định hướng quan trọng của đổi mới chương trình giáo dục phổ thông Việt Nam. Tuy nhiên, đến nay chưa có khung năng lực STEM trong dạy học ở nước ta. Khung năng lực dạy học STEM mang đồng thời hai ý nghĩa quan trọng. Một là: người học chủ động lập kế hoạch, tìm kiếm thông tin, xác định nội dung, phương pháp và bổ sung kiến thức liên môn từ khi bắt đầu quá trình rèn luyện. Hai là: định hướng cho việc đánh giá mức độ biểu hiện tương ứng cho từng sinh viên sư phạm. Bài viết trình bày quy trình xây dựng khung năng lực dạy học STEM đồng thời đề xuất một số cách sử dụng chúng trong quá trình đào tạo tại các trường Đại học Sư phạm.

Từ khóa: Khung năng lực; Dạy học STEM; Đại học sư phạm; Sinh viên sư phạm hóa học.