Technology development in thermochemistry materials

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Abstract. Thermochemistry is an important basic concept in studying advanced chemistry. Thermochemistry is very important to understand correctly and easily. This research aims to develop technology that can facilitate understanding of thermochemistry. This research is a research and development research (R & D). In this research, a technological development can be produced which can be used to facilitate understanding of thermochemical concepts. This research resulted in a framework of thermochemical material integrated with science (biology, physics), mathematics, engineering, ICT technology.

1. Introduction
Thermochemistry is the part of chemistry that studies the change in energy or heat of a substance that accompanies a reaction. In thermochemistry, the concepts of energy change, heat and temperature, enthalpy, standard formation enthalpy ($\Delta H^\circ_f$), standard decomposition enthalpy ($\Delta H^\circ_d$), standard combustion enthalpy ($\Delta H^\circ_c$), standard evaporation enthalpy ($\Delta H^\circ_e$), standard sublimation enthalpy ($\Delta H^\circ_s$), standard melting enthalpy ($\Delta H^\circ_m$), standard combustion enthalpy ($\Delta H^\circ_c$), standard dissolution enthalpy ($\Delta H^\circ_d$), standard evaporation enthalpy ($\Delta H^\circ_e$), standard sublimation enthalpy ($\Delta H^\circ_s$), standard melting enthalpy ($\Delta H^\circ_m$), type of calorimeter, thermochemistry in daily life, systems and environment, exothermic reaction, endothermic reaction, Laplace's law, Hess's law, energy conservation law, delta's H reaction, delta's H reaction by calorimeter, delta’s H of reaction by Hess's law, delta's H reaction by means of bond energy, delta’s H reaction with the standard enthalpy. With so many complex concepts, formulas and calculations that must be understood in thermochemistry, it requires an integrative technology and design that can combine science, mathematics, engineering, technology in thermochemistry to facilitate understanding of thermochemistry. STEM (science, technology, engineering, and math) is the fifth-fastest-growing industrial cluster in the South and the seventh-largest employer with projected employment of 2.6 million workers by 2020. In order to prepare our students to take advantage of the vast opportunities in this field, we must equip students with the knowledge and skills to embark upon a STEM pathway successfully and, ultimately, a high-demand STEM-related career [1]. STEM education recommendations reflect the promotion of a fully integrated approach, targeting four priority areas to drive the integrative work of state math and science standards. At its simplest, the term STEM stands for the four primary disciplines families of Science, Technology, Engineering, and Mathematics [2]. Science is the study of the natural world. Including the law of nature associated with physics, chemistry, & biology. Technology is the natural world to meet the needs and wants of people. Engineering is applying Math and Sciences to create Technology. Mathematic: number, operations, Patterns, and Relationships [3]. These four priority areas are curriculum and instruction, student achievement, educator professional development, and community and postsecondary partnerships.
Some research on how to integrate chemistry and engineering to produce a new concept that is easier to understand has been done before. Sustainable chemical engineering processes are best designed, implemented, and realized by taking a principled, sustainable, and green chemistry and engineering design approach from project inception. The application of these principles helps to frame in a manner that the scientist or engineer thinks about any given problem, process, or service they are working to implement. This chapter will lay out how chemistry and engineering principles must be integrated in the conceptualization and design in order for a more sustainable chemical engineering process to be developed [4]. Framework for analyzing placement of and identifying opportunities for improving technical communication in a chemical engineering curriculum [5]. Development research with ASPEN PLUS which aims to increase understanding of engineering chemistry, which previously used ordinary experiments, is proven to improve student understanding [6].

Thermochemistry STEM is a new material framework that integrates science (biology, physics) mathematics, engineering and technology in an integrated manner that is easily understood and applied in everyday life. This thermochemical material framework will form the basis of concepts for further understanding of chemical materials.

The flipped classroom is also using electronic media into the self-learning process before the student enters the class. Describes a learning model that incorporates direct learning with constructivist learning experiences while the main goal using a flipped classroom strategy is to provide a self-learning environment for students in solving problems. Nevertheless, the teacher retains control over student learning activities [7]. The shortage of graduates in Science, Technology, Engineering, and Mathematics STEM (STEM) has led to numerous attempts to increase students' interest in STEM. One emerging approach with the potential to improve student's motivation for STEM is an integrated STEM education approach [8]. Today, it is a commonplace to say that relationships between science, technology, engineering, and mathematics disciplines are becoming increasingly more influential, permeating the workplace and creating new demands for solving daily work-related problems [9]. In this study, the STEM education approach is going to be implemented in a flipped classroom learning environment. In a traditional class, the teacher conveys learning in class and then gives homework to students to do after class. Whereas in a flipped classroom, things are done the other way round. The teacher "delivers" lectures before class in the form of pre-recorded videos and spends class time engaging students in learning activities that involve collaboration and interaction [10]. What is done is the opposite; the subject matter is delivered by the teacher through video recordings, while class time used for direct interaction and collaboration between the teacher and students in the learning process. In this case, the teacher prepares material, can be in the form of video recordings, or links to internet media that can be accessed by students independently, as preparation material before doing direct learning in the classroom. The ultimate goal of Flipped Learning is to provide a student-centered learning environment [11]. The primary purpose of flip learning is to provide a student-focused learning environment. In this case, students are given space to study independently, build their knowledge; then, in class, the teacher guides students in solving problems. The flipped classroom is a teaching method that delivers lecture content to students at home through electronic means and uses class time for practical application activities [12]. Figure 1 is the difference scheme between the flipped classroom and the traditional class [10].
The key to implementing Thermochemistry STEM programs is integration with the curriculum. Preparations that must be prepared include subjects, materials, learning strategies, time, media, and evaluation tools. Chemistry is a science subject that is considered severe because it contains many complex mathematical calculations and many formulas that must be memorized. Besides, chemistry is less desirable by students, because it is considered less relevant to daily life.

2. Method
This study attempts to develop Thermochemistry STEM in the Flipped Classroom learning environment. This study was a research and development (R&D) of STEM education in the flipped classroom learning environment in high school. The study followed Steps of System Approach Model of Educational Research and Development by Gall, Gall, and Borg [13].

Some research studies on chemistry development include: Improvement of the learning and assessment of the practical component of a process Dynamics and control course for fourth year chemical engineering students. The focus of this work was to improve the learning and assessment of the practical component of the Process Dynamics and Control fourth year Chemical Engineering course at the University of KwaZulu-Natal in South Africa and consequently, the general performance in selected aspects of the course. An increase in the general understanding of the module content for the aspects assessed in the new practical was observed, as quantified by an increase in the pass rate and average mark of the cohort regarding the selected aspects specifically, in comparison to previous years. [6] “Enhancing the autonomy of students in chemical engineering education with LABVIRTUAL platform”: developing different approaches to supplement scientific background and further develop the ability for autonomous and critical thinking in students [14]. A framework for incubating independent learning: The study demonstrates an effective implementation of the framework with associated benefits for the learner in the areas of cognitive skills (creativity and critical thinking), metacognitive skills [15]. The findings from this research form the basis for us that material in chemistry, especially thermochemistry, can be developed into a material framework that is more easily understood by integrating it with mathematics, and technology.

This study uses qualitative and quantitative data; thus the research approach is mixed-method research that combines qualitative and quantitative approaches [16]. Primary data derived from interviews, observations and secondary data from document studies are processed qualitatively. Data from interviews, observations, and secondary data from document studies in preliminary research and formative evaluation are processed using triangulation.

Pre Test and Post Test are given to students to be then assessed by the teacher using an assessment rubric. Data from Pre Tests and post Tests are processed using statistical analysis, which is the average test to compare the mean values of the PreTest and post Test. After processing the data, the results are interpreted as research findings.

Approaches that can be used in the STEM learning model include (Figure 2): (a) The Silos Approach, where each STEM discipline is taught separately to maintain the domain of knowledge within the
boundaries of each discipline; (b) The embedded approach, emphasizes more on maintaining the integrity of subject matter, rather than focusing on interdisciplinary subjects, the material on the embedded approach is not designed to be evaluated or assessed; (c) An integrated approach, where each STEM field is taught as if integrated into one subject. In learning science, students must be allowed to design and carry out empirical investigations and link those investigations to the core of the knowledge that students are learning [17]. Specific instructional objectives in STEM-based learning should be in the form of explicit sentences of student behavior that will emerge after students master the skills and knowledge taught by the teacher [18]. The approach used this research is the embedded approach, in thermochemistry material [19].

![Figure 2](image)

**Figure 2.** Depicts the embedded approach to STEM education.

Embedded STEM instruction may be broadly defined as an approach to education in which domain knowledge is acquired through an emphasis on real-world situations and problem-solving techniques within social, cultural, and functional contexts (Chen, 2001). In practice, embedded teaching is effective instruction because it seeks to reinforce and complement materials that students learn in other classes (ITEEA, 2007).

3. Results and discussions

The concepts, formulas, application of heat and energy calculations in thermochemistry will be easily understood and applied in daily life if this material is integrated with mathematics, technology, and science. Thermochemical material is presented in the form of virtual labs, experimental videos of heat and energy transfer, and interactive videos in enthalpy calculations.

Thermochemistry becomes a new unit of material which is an integration of mathematics, engineering, other sciences: physics and biology, and ICT. In thermochemistry, for example, the green element is included in the area of biological science. Calculation of heat will include the concepts of physics about the law of conservation of energy and so on. In the concept of thermochemistry here thermochemistry will be developed in relation to other sciences whose use is very close in everyday life.

By developing the Thermochemistry STEM model, the material forces students to understand other science materials simultaneously and provides meaningful learning. Thermochemistry becomes a pilot material in using STEM, because in thermochemistry it contains mathematical calculation formulas, impacts on the biological environment and is closely related to physics, and is communicated with ICT technology. Other chemical materials may not be integrated as well as thermochemistry.

Thermochemistry STEM is not used in all chemistry materials, only emphasizes material that contains mathematical calculations, and needs to be delivered using a flipped classroom learning environment. Flipped classroom learning environments are used because from several research results, and it is found that flipped classrooms can improve the attitude of being independent, communicative, critical, and able to solve difficult problems [10].

4. Conclusion

STEM thermochemistry becomes a new material framework that integrates science (biology, physics) mathematics, engineering and technology in an integrated manner that is easily understood and applied in everyday life. This thermochemical material framework will form the basis of concepts for further understanding of chemical materials.
Thermochemistry STEM recommendations reflect the promotion of a fully integrated approach, targeting four priority areas to drive the integrative work of state math and science standards. These four priority areas are curriculum and instruction, student achievement, educator professional development, and community and postsecondary partnerships. In this Thermochemistry STEM model used practicum video media, virtual lab, or learning links to support the flipped classroom learning environment.

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