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Integrating Project-Based Learning in Chemical Thermodynamics Education

Marie-Noëlle Dumont[a*], Antoine Rouxhet[a], Nathalie Job[a], Grégoire Léonard[a]
[a] Department of Chemical Engineering, University of Liège, Belgium
* Corresponding Author: mn.dumont@uliege.be

ABSTRACT

The Chemical Thermodynamics course at the University of Liège is designed for Bachelor of Engineering students and first-year Master's students in Chemical Engineering and Materials Science. The course is divided into two parts: **1. Pure components**: Methods for evaluating the physical and thermodynamic properties of pure substances, including predictive methods and equations of state. **2. Mixtures**: Methods for mixtures of different substances, including multiphase equilibria and thermochemical quantities of reactions. Projects are introduced at the beginning of each part and undergo formative evaluation at mid-term. The goal is to enhance students' understanding of theoretical concepts through authentic projects and maintain their motivation by clearly defining weekly tasks. This paper focuses on re-phasing existing activities using a three-phase competency evaluation model. **Phase 1**: Students are assigned a project, a complex task requiring the selection and combination of several elementary tasks performed during tutorials. **Phase 2**: The project remains, but the complex task is broken down into elementary tasks. Each week, at the end of the tutorial, students receive explicit instructions to progress in their project using newly acquired knowledge. For each elementary task, students determine the procedure to implement among those they are supposed to know. **Phase 3**: During the tutorials, students are presented with simple, decontextualized tasks corresponding to the elementary procedures needed for the complex task from Phase 1.

Keywords: Education, thermodynamics, chemical thermodynamics.

INTRODUCTION

This study focuses on an elective course for third-year Bachelor of Engineering students who wish to pursue a Master's in Chemical and Materials Science Engineering or in Energy Engineering at the School of Engineering. It is also a mandatory course for external students who want to join one of the master's programs and come from another faculty or university.

The course is conducted over 13 weeks in the Spring semester, on Monday afternoons, with 2 hours of theory followed by 2 hours of exercises. Each year, there are between 30 and 50 students enrolled in the course. Those students have already completed a foundational course in thermodynamics.

PROBLEM DESCRIPTION

In this course, there is a significant amount of new knowledge to acquire. These concepts were traditionally taught in a linear fashion, with each new theoretical step followed by a series of corresponding exercises. The exam consisted of an integrative exercise, which students often failed because the triple alignment (Expected learning outcome – Activity – Assessment) was not respected. To address this issue, we introduced an integrative project to train students to make connections between the different subjects taught.

However, proposing a project is not enough. Students must also mobilize and integrate a set of theoretical resources. Viau [1] defines motivation as "a phenomenon that originates from the learner's perceptions of themselves and their environment, resulting in their choice to engage in and persist with the proposed educational activity, with the goal of learning." Therefore, it

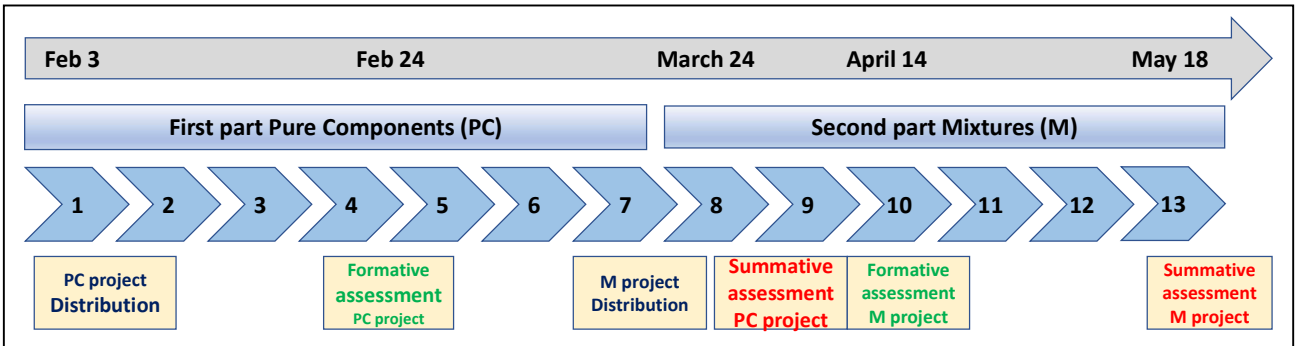

Figure 1: Organisation of the chemical thermodynamics course

is not only necessary to propose an real-world engineering project and support students in integrating resources, but also to present it within a context that appeals to the student's motivation and for which they feel capable to take positive actions.

THREE-PHASE COMPETENCY EVALUATION MODEL

To enhance students' sense of competence, the project structure was modified based on the three-phase competency evaluation model [2]:

Phase 1: Students are given an "authentic" project, complex in that it requires selecting and combining several elementary tasks performed during tutorials (tutorials). Two project assignments are distributed in weeks 1 and 8, at the beginning of each part of the course, pure components (PC) and mixtures (M).

Phase 2: The complex project task is broken down into elementary tasks. Each week, at the end of the tutorial, students receive explicit instructions to advance in their project using the knowledge acquired during the tutorial. This set of instructions will ultimately enable students to complete the overall complex task. It is their responsibility to determine the procedure for each elementary task from those they are supposed to know. Notice that all the sub-questions are not available when distributing the projects to avoid overwhelming and discouraging students with a task that might seem too difficult.

Phase 3: During the tutorials, students are presented with a series of simple, decontextualized tasks in the form of exercises. These tasks relate to the elementary procedures that need to be mobilized and progressively accumulated to accomplish the complex task from Phase 1. The order of questions in the project is phased with the exercises seen in the tutorials so that each week students can solve one or more additional questions.

COURSE ORGANISATION

The course is organized following the calendar presented in Figure 1. It is made of three main parts: theoretical course, exercises and projects. The theoretical course consists in in-person or recorded lectures and multiple-choice tests available each week after the class.

Regarding exercises, two types of activities take place, in person or remote. In-person activities consist in (1) Review of the previous week's theory tests and analysis of difficulties encountered by students; (2) Explanation of theoretical points necessary for solving the exercises; (3) A sample exercise solved aloud on the board; (4) Exercises of the same level solved by students with the possibility of collective discussion of the methods used. Remote activities include (1) a weekly worksheet available to prepare for the exercise sessions; (2) Step-by-step resolution of various exercises in recorded versions.

Finally, the projects, that account for 40% of the final grade, follow some guidelines: (1) Free choice of partner, with projects done in pairs; (2) Projects rooted in reality; (3) Project availability from the beginning of the course. A formative assessment is offered at mid-term. Feedback is provided to students to help them improve their report before submitting the final version.

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