An E-learning Bot for Bioprocess Systems Engineering

Simoneta Caño de las Heras, Mark Nicholas Jones, Krist V. Gernaey, Ulrich Krühne, Seyed Soheil Mansouri

Process and Systems Eng. Centre (PROSYS), Dept. of Chemical and Biochemical Eng., Technical University of Denmark, Søltofts Plads, 2800 Kgs. Lyngby, Denmark
seso@kt.dtu.dk

Abstract

Receiving an engineering education is not a smooth path and in the last years, several digital platforms have been developed with the aim to help the students in the field. Nonetheless, the initial efforts to use digital platforms have not yet been successful, partly due to the lack of support to the teachers, the lack of motivation strategies inside the platforms or the loss of the social interaction, which is key in a collaborative learning process. Collaborative learning integrates the interaction between the students and the teacher, or in the case of digital learning, with an educational software. However, it is difficult to provide such a frame of interaction between learners inside an educational software. Therefore, a chatbot is proposed with its own design and architecture which behaves like a “friend” or colleague in the education, here applied to bioprocesses. Along with the chatbot architecture, it is explained how it is integrated in the learning design through its database. This tailored database contains training example dialogs through questions raised by students from a course on Bioprocess Technology, while it also collects their common mistakes, etc. Moreover, this database contains a novel system of twin databases; one with correct information and another with small errors. Using this system, the chatbot provides a more accurate representation of a learner’s peer and triggers critical thinking. Finally, the chatbot architecture is embedded inside a prototype open-source Educational Virtual Bioprocess Plant developed by the Department of Chemical and Biochemical Engineering of the Technical University of Denmark, called FermProc. Keywords: Knowledge transfer, Bioprocess, Chatbot, Process System Education.

1. Introduction

During the past two decades, our world has drastically changed due to the use of internet in our daily life and the democratization of personal smartphones and computers. It has affected our means of communication and added new societal dimensions with economic implications. In the case of education, the creation of massive open on-line courses (MOOC) (Conole, 2016), educational computer games (Zendesk, n.d.), or educational simulators (Dyrberg, et al., 2017; Ebner & Holzinger, 2007) has demonstrated a clear interest in using digital platforms in teaching. Moreover, in the case of higher and tertiary education, there has been a growing need for flexible training towards continuing education and professional training, endorsing a learning outside the classroom supported by digital tools. However, the success in the integration of digital platforms as learning tools has not been as expected with a dropout rate of about 96 per cent on average over five years (Reich & Ruipérez-Valiente, 2019) in on-line courses.
This could be explained by the need of support for the instructors to create and integrate online content, the lack of institutions offering online education (Brahimi & Sarirete, 2015), or the failure of simulators in engineering education in motivating the students (Kiili, 2005), amongst other factors. A reason behind unsuccessful integration of digital technology had been the loss of normal interaction that occurs in a real classroom or laboratory as the students are isolated from their peers and instructors (Balamuralithara & Woods, 2009). Therefore, students miss a collaborative learning experience, i.e. they miss the social and environmental elements in their traditional learning.

In this work, we intend to develop a collaborative e-learning for bioprocess systems engineering, which is integrated inside a computer-aided tool. Bioprocess development reaches from discovery to distribution of bio-products. Therefore, it is a necessity for engineering students to gain the ability to connect and use the knowledge and competences that those students acquire during their education. This is a challenge that can be tackled through a knowledge transfer computer-aided tool, in the form of a chatbot.

2. Collaborative e-learning

Collaborative e-learning (Figure 1) is a type of learning process. Here, a computer-aided media (acting as a teacher) provides the content, task and the assessment to the students. On the other side, a peer (the chatbot) communicates with the learner, who compares, argues and reflects with itself and the chatbot about ideas or practices. Although it is part of a natural learning process (Laurillard, 2009), it must be actively considered during the design of the learning experience.

Collaborative e-learning has been investigated through the use of chats (Monahan, et al., 2008) and in fewer cases, chatbots (Kane, 2016). A chatbot is a computer program that works as a conversational agent and has huge potential as helper in education. A previous study had investigated the use of a chatbot for a negotiated learner model (Kerly, 2009), finding an improving accuracy in students’ self-assessment. In another case, the co-development of a chatbot with students was tested, by incorporating their own questions, which increased their motivation and interest for the subject (Crown, et al., 2011). However, in those cases the chatbot is an independent tool, not supported by an...
educational software that provides them with tasks, content…, and it lacks some of the characteristics of a peer, like the possibility of being wrong. Mistakes are rather usual to make and critical thinking is an important tool in the education of process engineers. Therefore, collaborative e-learning provides a frame not only for the students to reflect upon and share ideas, but also to be critical, using their own knowledge while an external agent attempts to influence them.

3. Chatbot Architecture

The chatbot is acting as a peer inside the collaborative e-learning (Figure 1). The software architecture can be seen in Figure 2.

This chatbot is developed considering its objective as an educational tool for process engineering applied to bioprocesses. Based on its educational frame, the chatbot includes:

- **Engage the user.** It needs to be contextual and focused on the individual and on the objectives of the process (operational, economic and sustainability). For example, some enjoyable facts about the process and industrial information can be used to refer back to the main topic.
- **Learn.** Leverage machine learning to develop context and resolve issues in an automated fashion.
- **Communicate.** Create a comfortable and adapted mode of communication with the use of gifs, emojis or memes.
- **Promote curiosity.** By providing a possibility to connect one bioprocess concept to another.

Figure 2. Chatbot architecture, in which is represented the transport of information and the different processes that form the chatbot.

The chatbot (Figure 2) is composed of a machine learning (data-driven) layer and a data layer. The machine learning layer contains the natural language processing (NLP), understanding (NLU) and generator (NLG) as well as the decision engine, and is programmed in Python and TensorFlow using predefined routines.

Meanwhile, the data layer is in charge of storing the information used in the training of the chatbot and therefore, it embeds the chatbots’ specifications. Along other routine
dialogs, the chatbot database involves specific example dialogs for training purposes, information related to bioprocesses and information related to the pedagogically oriented software in which it is implemented. The training example dialogs are a collection of questions of the Bioprocess Technology course, a course shared by the Bachelor of Science study plans of Human Life Science Engineering, Biotechnology and Chemical Engineering at the Technical University of Denmark, along with other sources of information. In this course, undergraduate students learn to do systematic mass and energy balances, to analyse and predict fluid behavior, and to design basic equipment used in bioprocess engineering (DTU, 2019).

An example question from a student used in the training dialog database has been:

Student: “In pumps, I am seeing two equations for the Net Positive Suction Head (NPSH); one with all the common terms and another one that it is missing the velocity term. Why is that?”

In this action, the Natural Language Processing (NLP) and Natural Language Understanding (NLU) modules, that use machine learning in Python, extract entities such as equation, NSPH, missing, velocity, and intents, like containNSPH (the verb and the noun of the sentence). Then, it performs a comparison through the information collected from the database and the Natural Language Generator (NLG) will provide a reply:

Chatbot: “It is due to the calculation of the NPSH in a specific point in order to calculate the net positive suction head, not needing the velocity. To get more information, I like this one: http://www.pumpschool.com/applications/NPSH.pdf (explained the different between the NPSH available and required and the different terms)”

As it has been briefly mentioned, a novel feature of this chatbot is confronting misleading ideas or wrong understandings during the training process. As the chatbot is acting as a peer learner inside the collaborative learning (Figure 1), it is possible that a peer learner will give a false advise. Thereby, we hope to engage the students in the necessary critical thinking. In order to implement this feature, another database is developed (an evil twin database) that includes slightly wrong answers. This database can be activated by the students as a special feature. An example can be seen in Figure 3.

Furthermore, in the data layer, the two example dialog databases are connected together with a database developed for a pedagogically oriented software developed at the Department of Chemical and Biochemical Engineering of the Technical University of Denmark, called FermProc. The aim of FermProc is to be the educational software that presents the content and tasks to the students as well as feedback over the learning of
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bioprocesses and a revision of the content and activities after the action of the student (Figure 1) in the collaborative e-learning.

4. Software integration

FermProc is based on a previously developed systematic methodology (de las Heras et al., 2018). This computer-aided tool has its prime pedagogical objectives in training people in the area of bioprocess operation. The interactive prototype includes understandably described and implemented mechanistic models, the possibility to modify them, learning-hints, questionnaires, mini-games, and the possibility to learn by failure. However, FermProc was not yet integrating the use of collaborative e-learning inside the platform and in the next development stage, the chatbot is added inside the software architecture.

FermProc is a three-layer software architecture. In its current state, the chatbot is a parallel feature in the software architecture of FermProc, connected through a shared data layer as well as the graphic user interface (Figure 4). However, in the future development, the chatbot will pass to be inside of the “special features” of the application layer of FermProc, together with the multimedia resources, or bioprocess mini-games implemented.

Figure 4. Integrated software architecture of the chatbot and FermProc. In this schema, the two combined architectures can be seen and the flux of information either from the chatbot or from FermProc.

5. Conclusions

Complexity is an intrinsic part of process systems and understanding such complexity requires the connection of different subjects and knowledge that undergraduate and graduate students acquire during their education. Although digital platforms could be excellent tools, they present some issues such as the lack of interaction between peers as well as the sharing and comparison of information. In this work, we proposed the use of a tailored chatbot. Through its data layer trained by actual questions from the students,
we hope to simplify the work of instructors and reduce the fear of students to ask questions. Furthermore, as peers are not always right, a novel system of twin databases is developed. This twin database system aims at enhancing the critical thinking of the students as the chatbot will not always provide the correct answer but the mechanisms to evaluate if the answer is wrong. Although the chatbot is specifically trained for the learning of bioprocess system engineering, its design is generic and it can be expanded to other fields and areas. Finally, the chatbot of this work has been implemented inside an educational bioprocess prototype software (FermProc) to provide a complete environment for a collaborative e-learning process.

References


