Tournament Battle: Gamifying Bibliographic Research and Oral Argumentation Applied to Chemical Engineering Topics

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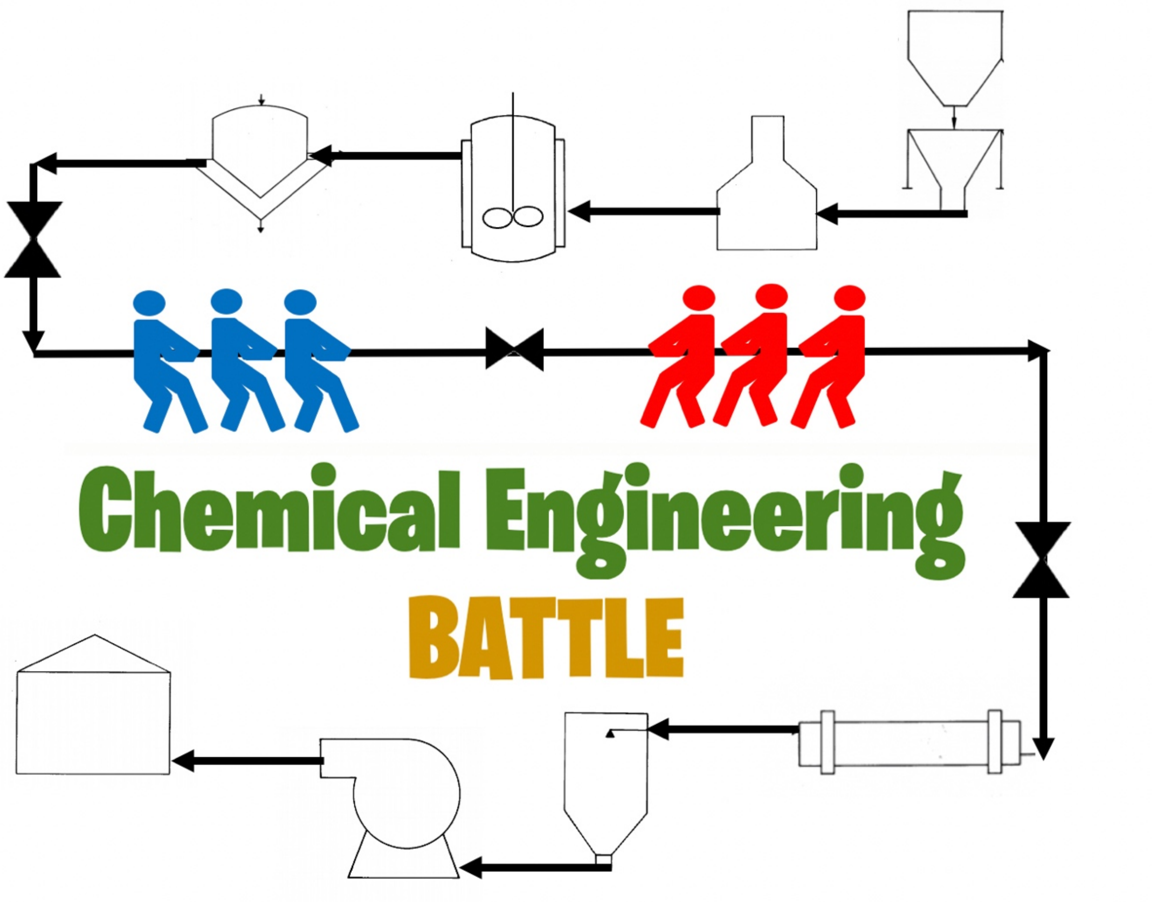
■ ABSTRACT

The purpose of this study is to present a learning activity that gamifies an argumentation exercise by combining both a bibliographic research activity and an oral argument. The exercise is organized as a competitive battle to engage and motivate students after training in bibliographic research. Students are divided into four teams of 4-7 students and are involved in a 2-round tournament starting with the Semi-Final round: the two winners of each semi-final meet in the final and the two losers in a playoff for third place. Each match is divided in two halves of 10 minutes: one to prepare their work and the second to present it and interact with the opposite team. At the end, the two spectator teams vote for the winning team and educators referee having the final decision. A symbolic prize (university goodies) is offered to the final winning team and each team is graded by the educators, on the basis of their two matches. The feedback received from students that participated in this exercise during the 2016-2020 period has been evaluated and corroborates the increase of motivation and teamwork through such activities. At the end, the advantages and limitations of such an activity are discussed.

■ GRAPHICAL ABSTRACT



■ KEYWORDS

General Public, Chemical Engineering, Collaborative / Communication / Writing, Humor / Puzzles / Games, Reactions /History, Philosophy/ Inquiry-Based/Discovery Learning, Physical Properties, Student-Centered Learning

■ INTRODUCTION

Generation Y, also known as the millennial generation or the Net Gen[1], refers to persons born between 1980 and 2010[2–4]. Most of the students from "Generation Y" in the Western world were born into a world of information technology; they are identified as preferring to multitask[5] rather than focusing on one thing at a time. Educators across disciplines are taking note of the challenges and opportunities associated with teaching this unique group[6]. Generation Y prefers to work in groups with hands-on experiences[7,8]. They enjoy trial and error[7]. Generation Y may not value reading and listening[9] to lectures as highly as has been traditional in education[6,7]. They want learning to be creative, interactive, and fun; and they enjoy thinking outside the box[10]. Core values of the generation Y include online social connectedness, teamwork, free expression, close relationships with authority figures[11], creativity, work-life flexibility, and use of technology[6]. Generation Y has characteristics that affect learning[12], but these differences are not necessarily weaknesses. To ensure success, educators need to understand that Generation Y cannot be forced into the mold of past generations and to adopt new strategies that adapt education to this generation. In this aim, educators have focused on several core areas: (1) interactive teaching with new technology, such as the use of Augmented Reality[13–16], video learning[17–20] or QR code[21–23] (2) gamification, using games[24–32] or trending ones such as escape games[33–38,19] or (3) more communication and systematic feedback[39]. To increase the "fun" aspect of the teaching, serious games[40] are a good solution as they permit the practice of communication, live feedback between students or from teachers, interaction and team building. Moreover, any form of competitive game may bring out the best in people and push them to excel, it allows students to exploit their real capabilities and maximize their true potential[41]. Collaborative activity coupled with immediate feedback within a practical context appears as a key to cater for the interests and habits of the "Generation Y". With this purpose in mind, some educators have tried to bring students together around a tournament activity (clash of chemists[42]) to create and share personal analogies explaining the difference between stoichiometric and nonstoichiometric reaction conditions in a recreational environment. Others have developed Battle Box[38] for practicing competitive escape games in a chemical environment. In all these examples, competition is not the central element, but it is a way of stimulating the students and making them more active than in a face-to-face class. These activities can therefore be linked to flipped and blended learning strategies which prioritize active learning during class[43]. The main objectives of this paper are to present an activity based on the use of a battle of debate (with a match and round-elimination system) following a training with a bibliographic research tool suited to chemical engineering. Argumentation can be defined as a dialogical activity where the positions of each can be transformed and enriched.[44] Argumentation appears as an essential operation for the development of reflective and critical thinking. Thus, the educational objectives for students are: (i) to develop skills related to argumentation; (ii) to develop skills related to finding scientific information autonomously; (iii) to develop skills related to cooperation and teamwork, and (iv) to develop skills related to oral fluency. The educational objectives of the teachers are: (1) to diversify learning situations, (2) to offer entertaining learning situations and assessments that make it possible to unlock blockages related to writing/conventional classes, (3) to offer learning situations that implement simple, rapid assessments, (4) to engage in intense exchange with students, and (5) to provide learning situations that foster both engagement and healthy competition between students, while promoting teamwork, cooperation, and peer review.

■ DESCRIPTION OF THE ACTIVITY

This activity has been conducted with students from the third year in Chemical Engineering and Environment courses at INSA Toulouse from academic year 2016/2017 to 2019/2020. It is part of an 18 hours classes, and it has been deployed after a series of lectures (5 h) covering the topic of chemical engineering. All these activities took place face to face before the lockdown due to the COVID19 epidemic in mid-March 2020.

The activity is composed of 4 distinct phases: (1) the research (2) the pooling (3) the battle and (4) the arbitration phase. The 24-student group is divided into 4 groups of 6 students. The teams can be imposed by the teacher in order to promote diversity or they can be formed randomly[45]. The team can choose their name, or it may be recommended to educators to come up with the group names such as a color (green, blue, red and yellow as depicted in Figure 1). The teacher team is composed of a librarian trainer and two teachers in chemical engineering playing the role of referee of the matches.

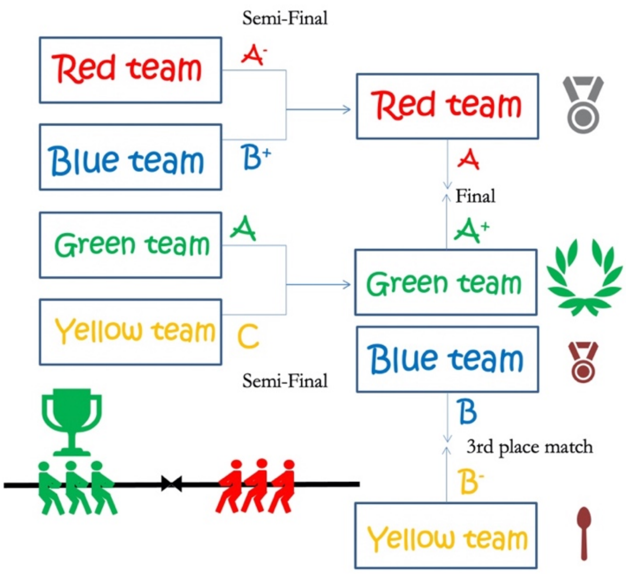


Figure 1. Tournament game scoreboard.

The first two games are the semi-finals, each winning team advances to the final, and each losing team advances to the playoff for third place (see Figure 1). Each team will thus play 2 matches in total.

The research phase

As part of the preparation for the Battle, an 85 minutes training session in bibliographic research skills is conducted to a group of 24 students in the early morning, from 8 am to 9:15 am, in a training room equipped with 12 computer stations and a video projector. The librarian trainer introduces the session, he presents the information skills training program, recalls the instructions and the breakdown of the morning and presents tools for finding scientific information about chemical engineering. The short-term goal is to prepare the students for the questions they will be asked during a ten-minute session facing two teams of students' (called the battle). At the end of this training session, they will be able to demonstrate their competences by knowing how to gather the maximum amount of reliable, quality information on a chemical process in a given time. The long-term objective is for them to be able to apply what they learnt in order to prepare their year-end report and also be able to reinvest them in a professional perspective. Based on the example of a classical process that will be the common thread throughout the activity, the trainer will gradually teach them to adopt an effective search strategy. Defining the need for information is the first step: it allows the students to refocus their research and save time. The trainer then presents the tools that are useful for defining concepts and key words, and essential terminologies which will allow them to access the various platforms of scientific publishers and databases.

At the same time, the trainer asks the students to use tools such as an encyclopedia of engineering techniques (e.g., a French technical and scientific documentary database - online with subscription[46]), then a terminological dictionary for French-English translation (bank of terminological files written by the Quebec office for the French language[47]), he broadcasted a short video on the use of the Wikipedia collaborative encyclopedia[48]. The training concludes with the presentation and online test of Ullmann's Encyclopedia of Industrial Chemistry[49], which provides comprehensive science and technology coverage in all areas of industrial chemistry. The third step is to teach the students how to build search equations by knowing how to use operators and advanced tool modules (truncation, Booleans, proximity, etc.). This is illustrated live by the trainer, always with the one chemical process serving as an example. After which a short period of discussion in the form of questions and answers on the student's ability to define the relevance criteria for reliability of printed or digital information in order to develop their critical thinking and vigilance. The trainer finally explains the interest of carrying out bibliographic research on the various scientific publishing platforms to which the university library has subscribed, emphasizing the quality, academic level and reliability of the resources presented. He explains the different access methods, such as: Elsevier's Science Direct and Web of Knowledge, international and multidisciplinary bibliographic and bibliometric documentary databases and also search engines: (scholar.google.fr and lens.org); the catalog of the Toulouse university library network (archipel.univtoulouse.fr); the open access platforms: HAL developed by the CNRS (hal.archives-ouvertes.fr), patent site (wipo.int/patentscope). To conclude this phase, the trainer reveals a flipchart giving the subject where the battle will take place. Subjects are chemical processes, e.g. the Toyo process, the Stamicarbon process, the chloralkali process, the Haber-Bosh process, among others. The librarian teacher stops his classes and lets the students begin their documentary research on the chemical process.

The pooling phase

The students are invited to work on the different aspects of the process that will enable them to implement an argumentation in response to a subject / a problem. At this point they know the "chemical process" but they do not know the exact question of each battle match. This is a very important stage in which the students apply what they have learned about bibliographic research, pooling their preparation and comparing their ideas. Students know that they are going to have to defend their argument collectively and the team consistency may be the factor that will make the difference during the battle.

Figure 2. Pooling phase for each of the 4 groups before the Battle.

The students have to work very seriously during this phase in order to gather the maximum of information and to share the best items, while ensuring that everyone understands the subject of the argument (Figure 2). Before the end of this phase of 90 minutes, the teachers-referees complete the match line-up (depicted in Figure 1) without the students.

The Battle

After a few words to introducing the rules, the teacher reveals the first two teams who will compete against each other on the model of a hip-hop battle[50] or an oratorical joust[51]. The two teams are chosen by drawing lots. From this point, students are expected to be able to present a question, a topic or a theme on the chosen chemical process. They must understand what is being said by others students and provide constructive criticism[52], answers, and finally respecting rules to the debate (speaking rules, listening rules, duration…).

The teacher then gives the subject of the first match (a particular point of the process, a unit operation, the utility of the molecule produced, drawing the flowsheet of the process, the advantages, and disadvantages of the process, etc.), the two teams then have 10 minutes' preparation time to adapt and share their knowledge on this specific subject. The two remaining teams, knowing they will face each other in the second match but not yet knowing their precise battle topic, may use this time to continue to strategize on the global subject. Five minutes before the end of the preparation time, the two competing teams are called in front of the battle white board (divided into two parts by a central line) to start writing/drawing important elements. Once the preparation time has elapsed, the battle starts, for a duration of 10 minutes. During the battle, each student is invited to speak, and everyone's contribution is considered important. It is not a matter of judging other students but of examining their proposal, thinking and rebounding on them. The error has a privileged place in the debate, being considered as a source of learning. During the battle, the "leader team" begins and the "challenger team" can stop them as soon as they identify a mistake or consider that something important was forgotten. The "challenger team" then becomes the "leader team" and can continue the presentation. The teachers play the role of referees: they must give the floor to each team, making sure the speaking time of each team is respected, may ask another speaker to replace his teammate, may ask the other team to confirm/negate a point that has just been stated by a team, questioning both teams at the same time, asking a team to question the other, etc. During the battle, the students of each team encourage each other widely during this session, getting caught up in the game. It is common to hear "go ahead and try!" when the student on the board is a little hesitant to try[53]. A good-natured competitive spirit often develops between the two teams, creating a real "confrontation".

The arbitration phase

At the end of each battle, the two other teams must designate the most convincing team, justifying their choice on criteria related to both knowledge and method. A smartphone voting system is used to collect the results. This is an important moment, in which the students progress in terms of methodology as they discuss, as a group, the validity of one example, or the quality of one explanation over another. Very quickly, students get caught up in the game and develop listening skills and peer assessment skills[54]. At the end of each vote, a score is given to each team (on the format: A, mastered, B, acquired, C, in the process of learning, or D, not acquired), the score is reported on the score table and one team is declared the winner (except for the final and the third-place match were teams can be *ex aequo*). The evaluation criteria include the quality, precision and richness of the technical vocabulary used in the field concerned and the structuring of the answers[55]. Preparation and argumentation are evaluated through the knowledge of the subject, the quality of the arguments, the respect of the number of interventions per member, and the teamwork. At the end of the activity, the scores will be averaged for each group as the final score for the session. During this phase, students realize that victory is disconnected from the score: a team can lose a match even with the grade A if the other team gives better explanations or accurate examples.

It should be noted that a small symbolic gift (goodies from the university) is offered to the winning team. The duration of the battle is 1 hour and 30 minutes, i.e., around 4 hours for the whole activity with the preparation phase and the research phase.

■ STUDENT'S EVALUATION

A total of 210 students participated in these activities. At the end of the session in the years 2018/2019 and 2019/2020 (106 students'), the teachers invited all students to evaluate the activity by completing a printed form containing twenty-one questions with responses based on a Likert[56] scale (the response rate was 97.2% - 106 answers). Data are presented in Figure 3 and Figure 4. In general, all statements showed high levels of agreement ("agree" and "strongly agree") on the benefits of the battle, ranging from 62.3% to 96.8% of those surveyed.

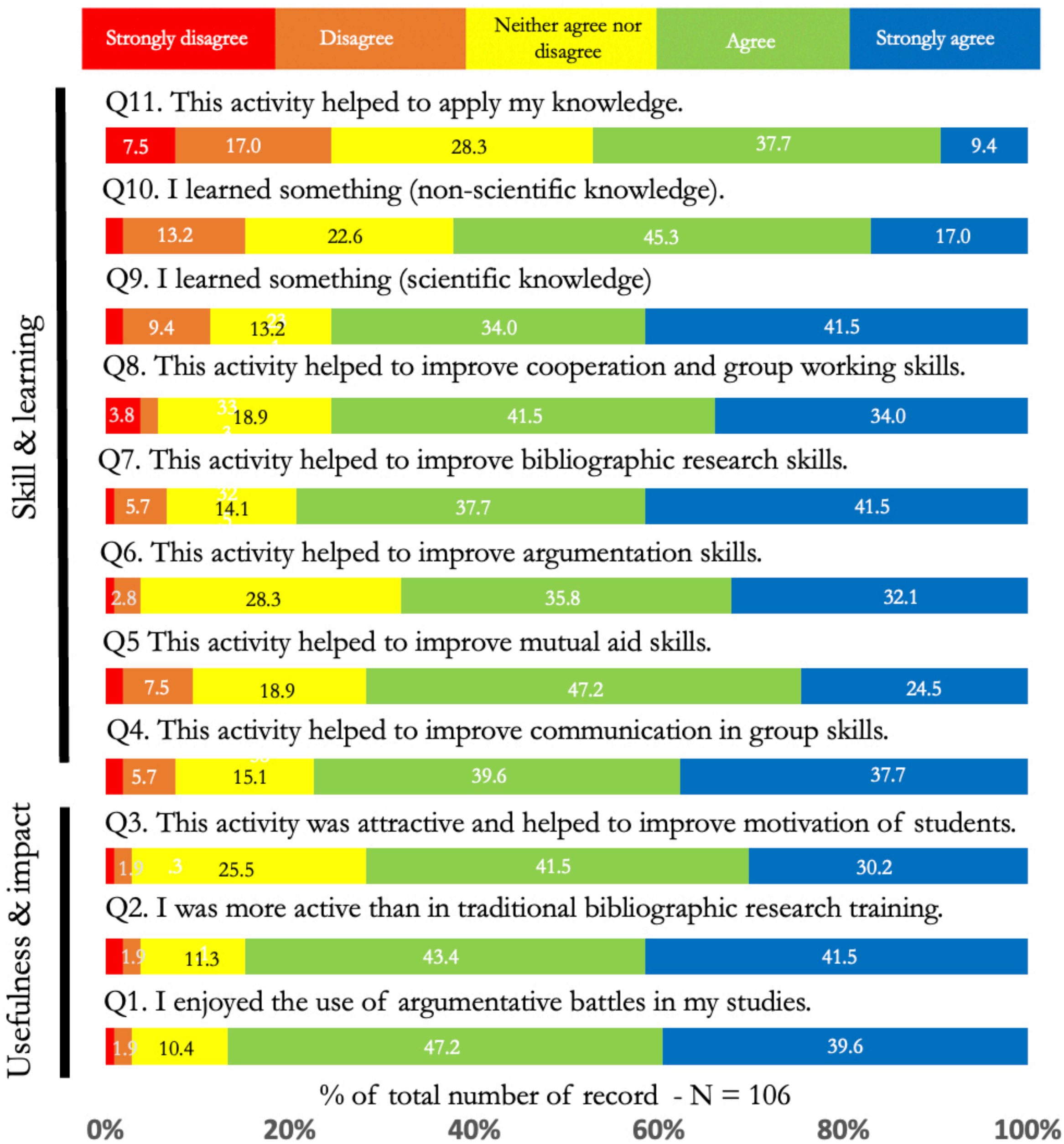


Figure 3. Student responses relating to the use of battle activity. Total number of respondents = 106 (academic years 2018/2019 and 2019/2020).

Concerning the usefulness and the impact of the activity: a large majority of students (Q1- Fig 3 - 86.8% versus 2.8%) enjoyed the use of battle in the courses and thought they were more active than in a traditional bibliographic research training session (Q2 - Fig 3 - 84.9% versus 3.7%). At INSA Toulouse, these training sessions take place yearly, with an increase in level or a focus on research/specialty over the year. A majority of students (Q3 - Fig 3 - 71.7% versus 2.8%) thought the battle was attractive and helped them to improve motivation.

Concerning the skills and information learned in the activity: a majority also agreed that the use of the battle helped them to improve skills for communicating in a group (Q4 - Fig 3 - 77.4% versus 7.5%), mutual aid skills (Q5 - Fig 3 - 71.7% versus 9.4%), argumentation skills (Q6 - Fig 3 - 67.9% versus 3.7%). The surveyed students broadly thought that this activity helped them to improve their bibliographic research skills (Q7 - Fig 3 - 79.2% versus 6.6%) and helped them to improve cooperation and group work skills (Q8 - Fig 3 - 75.5% versus 5.6%). In a free-response section of the questionnaire, students were asked to provide comments on the activity. One of them, concerning this last point on group skills, was a recommendation to avoid large groups of more than 4 students. At the end of the activity 75.5 % of the students (versus 11.3% - Q9 – Fig 3) felt they had learned scientific knowledge, and 62.3% of the students (versus 15.1% - Q10 – Fig 3) felt they had learned non-scientific knowledge. Finally, 47.2% of the surveyed students thought that the activity helped them to apply their knowledge (versus 24.5% - Q11 – Fig 3).

Concerning the reflection and the social interaction associated with the activity: a small majority (Q12 - Fig 4 - 52.8% versus 22.6%) thought this activity helped them to reflect on their course by making connections between the theoretical aspects of the course and their application. It is worth noting that the majority of students' thought that battle helped them to connect with other students (71.7% - Q13 - Fig 4 - versus 5.6%) and even, in a smaller proportion, with educators (54.7% - Q14 - Fig 4 - versus 18.9%). This could be explained by the fact that educators played the role of referees during the battle, managing and balancing the time between teams' explanations. A small majority of students (56.6% - Q15 - Fig 4 - versus 15.1%) agreed that the activity helped them to develop their critical thinking.

Concerning the organization and the feeling of the students: during the last year, some active rooms have been used to improve the interactions between students. These rooms are designed for active teaching and have been optimized to promote group work (with mobile tables and chairs and islands for groups of 6 students – Fig 2), better soundproofing to absorb the noise generated by group work, excellent Wi-Fi coverage and screens for each group. A large majority of the surveyed students in the last year of the study (N = 46) thought the use of the active teaching room was useful for the activity (70.4% - Q16 - Fig 4 - versus 12.9% - N = 46 - only surveyed in the last year). In terms of feelings, 35.8% of the students' felt stressed by time or failure (versus 41.5% not stressed - Q17 - Fig 4). In the free-response section of the questionnaire, some students reported that they would have preferred a longer time for research and coordination and that lack of time resulted in stress. Only 22.6 % of the students were disappointed by the result of the battle's matches (versus 47.1% - Q18 - Fig 4). This small value could be explained by the fact that a majority of 64.8% of students enjoyed voting and contributing to the choice of the winners (versus 9.3% - Q19 – Fig 4 – N = 46 – only surveyed in the last year).

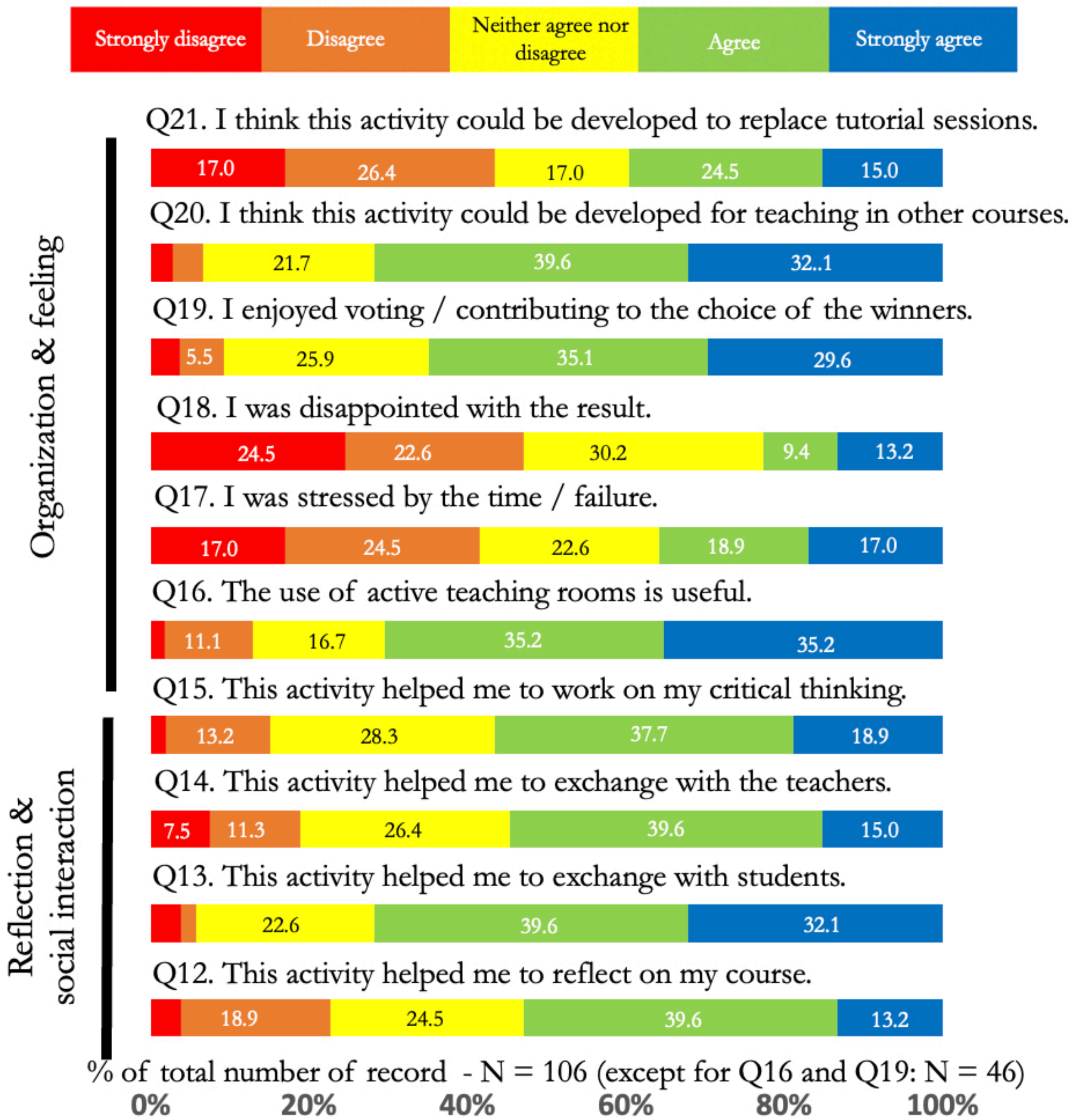


Figure 4. Student responses relating to the use of battle activity. Total number of respondents = 106 (academic years 2018/2019 and 2019/2020).

Finally, a large majority (71.7% - Q20 – Fig 4 – versus 6.6%) thought that battle is an excellent educational tool that could complement the classical ways of learnings in chemical engineering and could be developed for teaching in other courses. It is worth noting that the student panel was more dispersed in its choice concerning whether this activity could replace classical tutorial sessions (43.4% against versus 39.5% in favor – Q21 - Fig 4).

DISCUSSION

Used experimentally and improved by INSA students and educators for four years (2016/2017 to 2019/2020), this activity now experiences an overall positive result: (i) It promotes teamwork and cooperation among students: very quickly, students understand that the oral participation of all members of the group is a criterion for deciding between two teams (and it could be imposed by the teacher/referees). The students who are most comfortable with argumentation or who took the lead in the preparation phase take advantage of the pooling phase to help the students who have the most difficulty in progressing with the chemical process; (ii) It encourages the students to deepen their knowledge: after the first match of the activity, some students were no longer satisfied with the knowledge provided in the preparation table. They understand that the additional knowledge brought will sometimes allow them to make a difference in battles. They will therefore look for the most precise information; (iii) It promotes mutual listening and a co-construction of skills: during the arbitration phase, the students must spot errors or inaccuracies in knowledge; (iv) It facilitates the learning of knowledge because it mobilizes at least 4 conditions promoting long-term information retention: (a) to have understood the process to be able to apply it orally, (b) to mobilize active memorization by questioning teammates, not only during the mutualization phase but also during the battle phase with the opposite team, (c) to repeat the knowledge at extended intervals (2 matches per battle) and (d) to receive immediate feedback to rectify any misunderstanding and take advantage of the error. This activity was therefore a good strategy to engage students in bibliographic research training with a direct, original, and innovative application session. In our format, the activity was designed for a half-day but, in view of the free-response section of the questionnaire, we recommend applying it (if possible) in a full-day session to give the students more time to search for information, to interact with one another and to empower their communication skills. Educators need to be careful about the composition of the teams and the number of team members. Too small a number could lead to unbalanced teams in terms of level/leadership and too large a number will lead to difficulty for students to find their place and interact. From our experience, we propose an ideal number of 4-5 students per team. We also strongly recommend that the educator take the time to explain the rules clearly before the session, in order to explain that victory or ranking are not the goal of the session (a team can lose its 2 matches even with the maximum grade A), but communication, discussion, learning and fun are the only objectives.

The introduction of argumentative practices in science teaching profoundly modifies the respective roles of the teacher and the students[57]: it is no longer the authority of the teacher who establishes what is true by stating what has to be learned. It is the students who, through their activities, co-construct their knowledge. Working in a battle context means taking risks for teachers. Their position during the battle can be destabilizing because they lose the monopoly on questions and answers[58]. This attitude is the opposite of frontal teaching, where the teacher provides knowledge, and the questioning serves to verify understanding.

Changing the role of the teacher is the first necessary condition for the success of the battle. This raises the question of the position of the teacher in the debate. Should they intervene or, on the contrary, take a back seat to encourage the progression[58] of the students' questioning? A wide range of practices attempt to regulate these processes without really providing any precision. It is then up to the teacher to find the level of "guidance" necessary to conduct the debate[59]. During the battle, teachers may act as mediators and conduct the debate. Their participation should not prevent the confrontation of points of view.

The debate is therefore regulated by the moderator who structures the session by putting forward the position of the different student-debaters, by facilitating their exchanges, and in some cases by trying to arbitrate conflicts. The role of the teacher is to: (1) create a dynamic, tension and attention by reformulating certain divergences in the form of questions, sometimes by creating doubt.... "Are you sure?"[60] (2) Coach teams by encouraging them to defend their point of view by proposing a constructed argument. (3) Rhythm the battle. The two teams exchange their arguments one after the other, answering successive questions from the moderator in front of the audience. Speaking time is limited, to stimulate exchanges and get straight to the point. The moderator is therefore necessary to ensure that the rules of the game are respected. He is a referee, and a successful battle is one where the participants bring the debate by themselves by exploring the different aspects of their subject.

CONCLUSION

The purpose of this study was to present a learning activity that gamifies the argumentation between teams of students on a chemical engineering process. The present work therefore provides a creative and original activity based on the use of an argumentation exercise combining a bibliographic research activity with the oral expression of an argument. The feedback received from students that participated in this exercise for the 2016-2020 period has been evaluated and not only corroborates the increase of motivation and active behavior of students for such activities, but also confirms that this activity helped them to work on their communication skills, mutual aid skills, argumentation skills and bibliographic research skills. The educator should be careful about the length of the session (full day or half day but not less), the composition of the teams - with an optimal number of 4-5 members - and clearly clarifying the objectives before the session to avoid frustration and disappointment. Finally, the battle promoted exchanges between students and also, to a lesser extent, exchanges with the teacher in an entertaining and stimulating environment. This activity also promoted critical thinking and reflection on the students' course, which are important skills for students to develop. The pedagogical approach used with Generation Y students meets the needs and demands of this generation, while allowing the teacher to achieve their own goals. Generation Z will be a continuation of Generation Y, with exacerbated characteristics, especially with regard to creativity and the use of new technologies. The new generation will soon be at university, with even more expectations in terms of academic approach. The development of educational mediators is still in its beginning stages and promises to expand significantly in the coming years.

ASSOCIATED CONTENT

Tournament game scoreboard (PDF)

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Note: The authors declare no competing financial interest.

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