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

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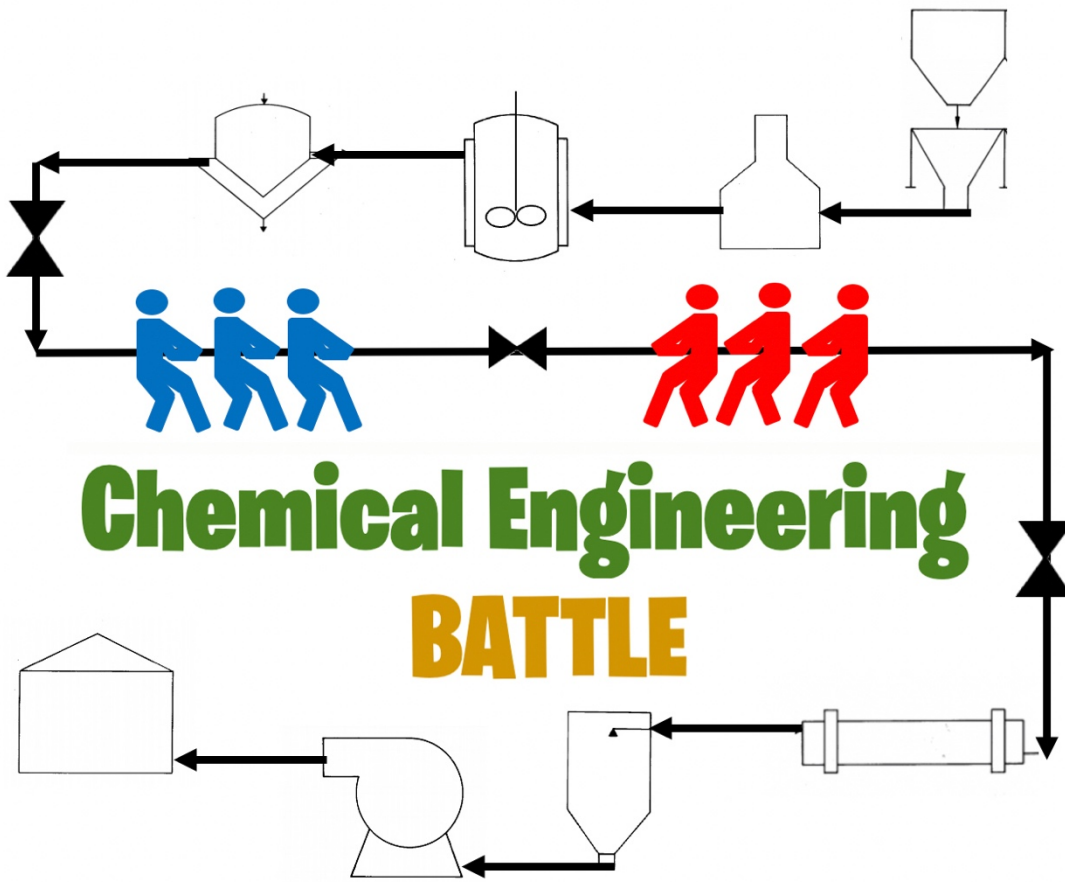
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■ ABSTRACT

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.

25 ■ GRAPHICAL ABSTRACT
26



27
28 ■ KEYWORDS

29
30 General Public, Chemical Engineering, Collaborative / Communication / Writing, Humor /
31 Puzzles / Games, Reactions /History, Philosophy/ Inquiry-Based/Discovery Learning,
32 Physical Properties, Student-Centered Learning

33 ■ INTRODUCTION

34 Generation Y, also known as the millennial generation or the Net Gen¹, refers to persons
35 born between 1980 and 2010²⁻⁴. Most of the students from “Generation Y” in the Western
36 world were born into a world of information technology; they are identified as preferring
37 to multitask⁵ rather than focusing on one thing at a time. Educators across disciplines
38 are taking note of the challenges and opportunities associated with teaching this unique
39 group⁶. Generation Y prefers to work in groups with hands-on experiences^{7,8}. They enjoy
40 trial and error⁷. Generation Y may not value reading and listening⁹ to lectures as highly
41 as has been traditional in education^{6,7}. They want learning to be creative, interactive, and
42 fun; and they enjoy thinking outside the box¹⁰. Core values of the generation Y include
43 online social connectedness, teamwork, free expression, close relationships with
44 authority figures¹¹, creativity, work-life flexibility, and use of technology⁶. Generation Y
45 has characteristics that affect learning¹², but these differences are not necessarily
46 weaknesses. To ensure success, educators need to understand that Generation Y cannot
47 be forced into the mold of past generations and to adopt new strategies that adapt
48 education to this generation. In this aim, educators have focused on several core areas:
49 (1) interactive teaching with new technology, such as the use of Augmented Reality¹³⁻¹⁶,
50 video learning¹⁷⁻²⁰ or QR code²¹⁻²³ (2) gamification, using games²⁴⁻³² or trending ones
51 such as escape games^{33-38,19} or (3) more communication and systematic feedback³⁹. To
52 increase the “fun” aspect of the teaching, serious games⁴⁰ are a good solution as they
53 permit the practice of communication, live feedback between students or from teachers,
54 interaction and team building. Moreover, any form of competitive game may bring out the
55 best in people and push them to excel, it allows students to exploit their real capabilities
56 and maximize their true potential⁴¹. Collaborative activity coupled with immediate
57 feedback within a practical context appears as a key to cater for the interests and habits
58 of the “Generation Y”. With this purpose in mind, some educators have tried to bring
59 students together around a tournament activity (clash of chemists⁴²) to create and share
60 personal analogies explaining the difference between stoichiometric and
61 nonstoichiometric reaction conditions in a recreational environment. Others have

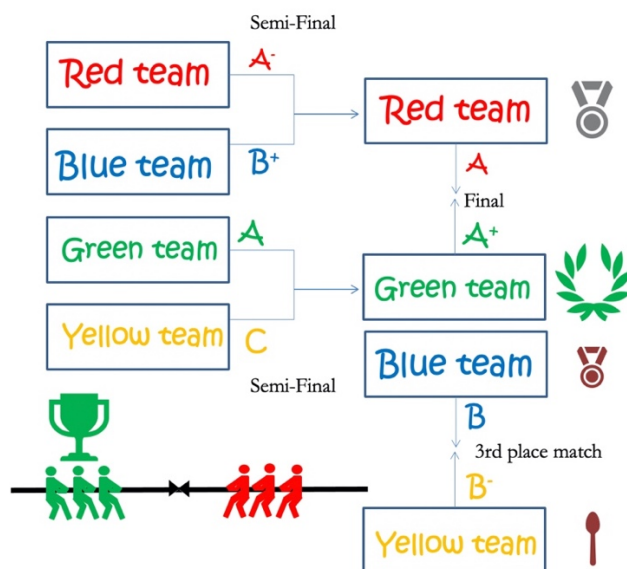
62 developed Battle Box³⁸ for practicing competitive escape games in a chemical
63 environment. In all these examples, competition is not the central element, but it is a way
64 of stimulating the students and making them more active than in a face-to-face class.
65 These activities can therefore be linked to flipped and blended learning strategies which
66 prioritize active learning during class⁴³. The main objectives of this paper are to present
67 an activity based on the use of a battle of debate (with a match and round-elimination
68 system) following a training with a bibliographic research tool suited to chemical
69 engineering. Argumentation can be defined as a dialogical activity where the positions of
70 each can be transformed and enriched.⁴⁴ Argumentation appears as an essential
71 operation for the development of reflective and critical thinking. Thus, the educational
72 objectives for students are: (i) to develop skills related to argumentation; (ii) to develop
73 skills related to finding scientific information autonomously; (iii) to develop skills related
74 to cooperation and teamwork, and (iv) to develop skills related to oral fluency. The
75 educational objectives of the teachers are: (1) to diversify learning situations, (2) to offer
76 entertaining learning situations and assessments that make it possible to unlock
77 blockages related to writing/conventional classes, (3) to offer learning situations that
78 implement simple, rapid assessments, (4) to engage in intense exchange with students,
79 and (5) to provide learning situations that foster both engagement and healthy
80 competition between students, while promoting teamwork, cooperation, and peer review.

81 ■ DESCRIPTION OF THE ACTIVITY

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

87 The activity is composed of 4 distinct phases: (1) the research (2) the pooling (3) the
88 battle and (4) the arbitration phase. The 24-student group is divided into 4 groups of 6
89 students. The teams can be imposed by the teacher in order to promote diversity or they

90 can be formed randomly⁴⁵. The team can choose their name, or it may be recommended
91 to educators to come up with the group names such as a color (green, blue, red and yellow
92 as depicted in Figure 1). The teacher team is composed of a librarian trainer and two
93 teachers in chemical engineering playing the role of referee of the matches.



94 **Figure 1.** Tournament game scoreboard.

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

98 **The research phase**

99 As part of the preparation for the Battle, an 85 minutes training session in
100 bibliographic research skills is conducted to a group of 24 students in the early morning,
101 from 8 am to 9:15 am, in a training room equipped with 12 computer stations and a video
102 projector. The librarian trainer introduces the session, he presents the information skills
103 training program, recalls the instructions and the breakdown of the morning and
104 presents tools for finding scientific information about chemical engineering. The short-
105 term goal is to prepare the students for the questions they will be asked during a ten-
106 minute session facing two teams of students' (called the battle). At the end of this training
107 session, they will be able to demonstrate their competences by knowing how to gather

108 the maximum amount of reliable, quality information on a chemical process in a given
109 time. The long-term objective is for them to be able to apply what they learnt in order to
110 prepare their year-end report and also be able to reinvest them in a professional
111 perspective. Based on the example of a classical process that will be the common thread
112 throughout the activity, the trainer will gradually teach them to adopt an effective search
113 strategy. Defining the need for information is the first step: it allows the students to
114 refocus their research and save time. The trainer then presents the tools that are useful
115 for defining concepts and key words, and essential terminologies which will allow them
116 to access the various platforms of scientific publishers and databases.

117 At the same time, the trainer asks the students to use tools such as an encyclopedia of
118 engineering techniques (e.g., a French technical and scientific documentary database -
119 online with subscription⁴⁶), then a terminological dictionary for French-English
120 translation (bank of terminological files written by the Quebec office for the French
121 language⁴⁷), he broadcasted a short video on the use of the Wikipedia collaborative
122 encyclopedia⁴⁸. The training concludes with the presentation and online test of Ullmann's
123 Encyclopedia of Industrial Chemistry⁴⁹, which provides comprehensive science and
124 technology coverage in all areas of industrial chemistry. The third step is to teach the
125 students how to build search equations by knowing how to use operators and advanced
126 tool modules (truncation, Booleans, proximity, etc.). This is illustrated live by the trainer,
127 always with the one chemical process serving as an example. After which a short period
128 of discussion in the form of questions and answers on the student's ability to define the
129 relevance criteria for reliability of printed or digital information in order to develop their
130 critical thinking and vigilance. The trainer finally explains the interest of carrying out
131 bibliographic research on the various scientific publishing platforms to which the
132 university library has subscribed, emphasizing the quality, academic level and reliability
133 of the resources presented. He explains the different access methods, such as: Elsevier's
134 Science Direct and Web of Knowledge, international and multidisciplinary bibliographic
135 and bibliometric documentary databases and also search engines: (scholar.google.fr and
136 lens.org); the catalog of the Toulouse university library network (archipel.univ-

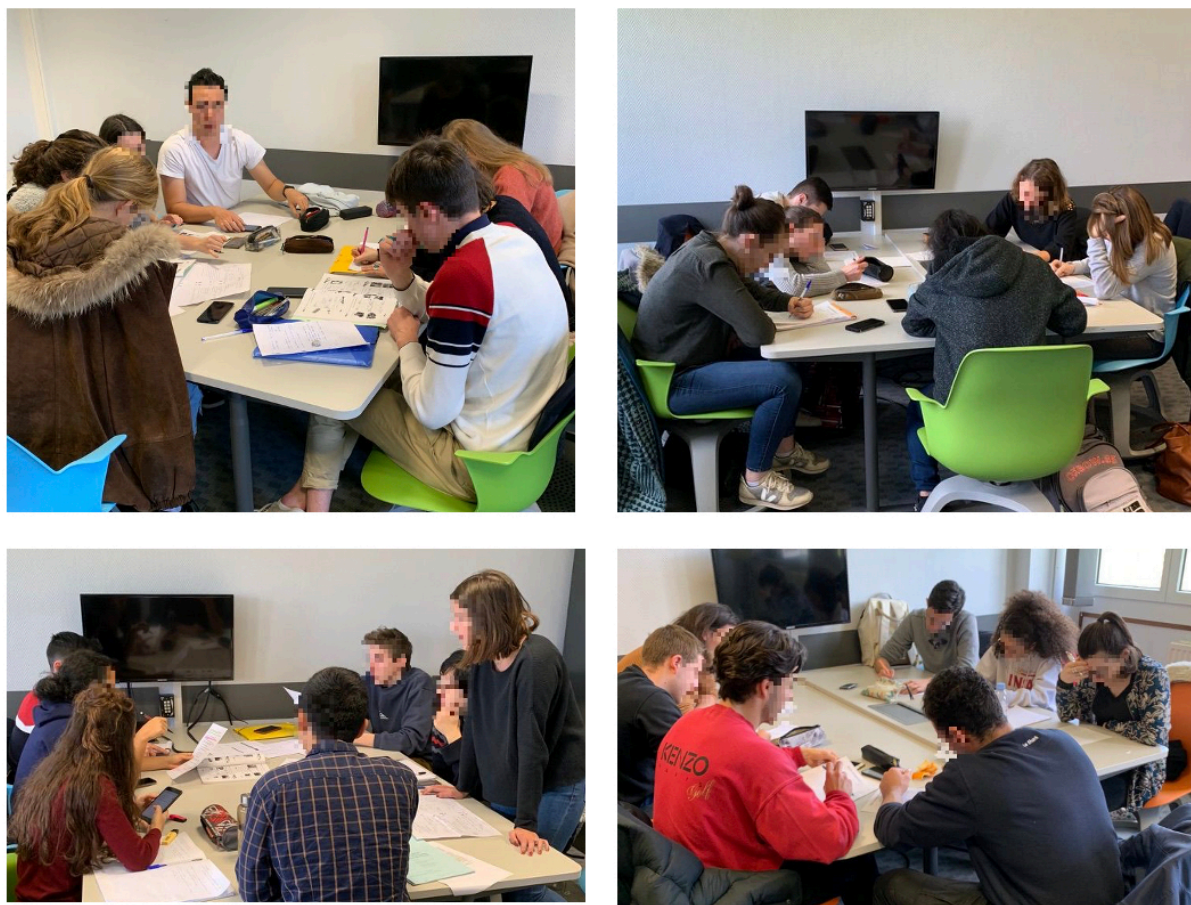
137 toulouse.fr); the open access platforms: HAL developed by the CNRS (hal.archives-
138 ouvertes.fr), patent site (wipo.int/patentscope). To conclude this phase, the trainer
139 reveals a flipchart giving the subject where the battle will take place. Subjects are
140 chemical processes, e.g. the Toyo process, the Stamicarbon process, the chloralkali
141 process, the Haber-Bosh process, among others. The librarian teacher stops his classes
142 and lets the students begin their documentary research on the chemical process.

143

144 **The pooling phase**

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

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

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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.

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The Battle

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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 battle⁵⁰ or an oratorical joust⁵¹. 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 criticism⁵²,

167 answers, and finally respecting rules to the debate (speaking rules, listening rules,
168 duration...).

169 The teacher then gives the subject of the first match (a particular point of the process,
170 a unit operation, the utility of the molecule produced, drawing the flowsheet of the
171 process, the advantages, and disadvantages of the process, etc.), the two teams then have
172 10 minutes' preparation time to adapt and share their knowledge on this specific subject.
173 The two remaining teams, knowing they will face each other in the second match but not
174 yet knowing their precise battle topic, may use this time to continue to strategize on the
175 global subject. Five minutes before the end of the preparation time, the two competing
176 teams are called in front of the battle white board (divided into two parts by a central line)
177 to start writing/drawing important elements. Once the preparation time has elapsed, the
178 battle starts, for a duration of 10 minutes. During the battle, each student is invited to
179 speak, and everyone's contribution is considered important. It is not a matter of judging
180 other students but of examining their proposal, thinking and rebounding on them. The
181 error has a privileged place in the debate, being considered as a source of learning.
182 During the battle, the "leader team" begins and the "challenger team" can stop them as
183 soon as they identify a mistake or consider that something important was forgotten. The
184 "challenger team" then becomes the "leader team" and can continue the presentation.
185 The teachers play the role of referees: they must give the floor to each team, making sure
186 the speaking time of each team is respected, may ask another speaker to replace his
187 teammate, may ask the other team to confirm/negate a point that has just been stated
188 by a team, questioning both teams at the same time, asking a team to question the other,
189 etc. During the battle, the students of each team encourage each other widely during this
190 session, getting caught up in the game. It is common to hear "go ahead and try!" when
191 the student on the board is a little hesitant to try⁵³. A good-natured competitive spirit
192 often develops between the two teams, creating a real "confrontation".

193 **The arbitration phase**

194 At the end of each battle, the two other teams must designate the most convincing
195 team, justifying their choice on criteria related to both knowledge and method. A

196 smartphone voting system is used to collect the results. This is an important moment, in
197 which the students progress in terms of methodology as they discuss, as a group, the
198 validity of one example, or the quality of one explanation over another. Very quickly,
199 students get caught up in the game and develop listening skills and peer assessment
200 skills⁵⁴. At the end of each vote, a score is given to each team (on the format: A, mastered,
201 B, acquired, C, in the process of learning, or D, not acquired), the score is reported on
202 the score table and one team is declared the winner (except for the final and the third-
203 place match where teams can be *ex aequo*). The evaluation criteria include the quality,
204 precision and richness of the technical vocabulary used in the field concerned and the
205 structuring of the answers⁵⁵. Preparation and argumentation are evaluated through the
206 knowledge of the subject, the quality of the arguments, the respect of the number of
207 interventions per member, and the teamwork. At the end of the activity, the scores will
208 be averaged for each group as the final score for the session. During this phase, students
209 realize that victory is disconnected from the score: a team can lose a match even with the
210 grade A if the other team gives better explanations or accurate examples.

211

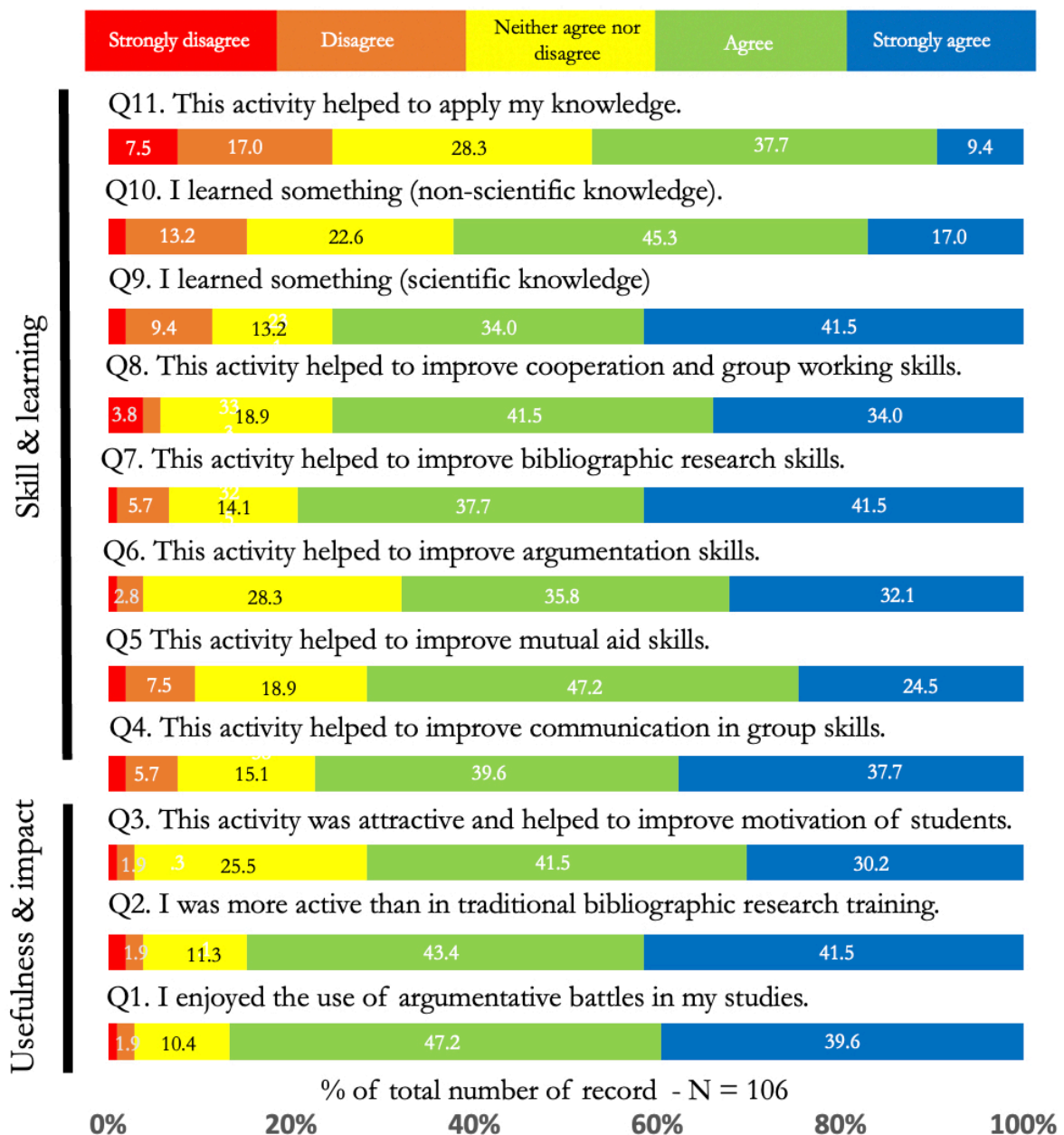
212 It should be noted that a small symbolic gift (goodies from the university) is offered to
213 the winning team. The duration of the battle is 1 hour and 30 minutes, i.e., around 4
214 hours for the whole activity with the preparation phase and the research phase.

215

216 ■ STUDENT'S EVALUATION

217 A total of 210 students participated in these activities. At the end of the session in the
218 years 2018/2019 and 2019/2020 (106 students'), the teachers invited all students to
219 evaluate the activity by completing a printed form containing twenty-one questions with
220 responses based on a Likert⁵⁶ scale (the response rate was 97.2% - 106 answers). Data
221 are presented in Figure 3 and Figure 4. In general, all statements showed high levels of
222 agreement ("agree" and "strongly agree") on the benefits of the battle, ranging from 62.3%
223 to 96.8% of those surveyed.

224



225

226 **Figure 3.** Student responses relating to the use of battle activity. Total number of
 227 respondents = 106 (academic years 2018/2019 and 2019/2020).
 228

229 Concerning the usefulness and the impact of the activity: a large majority of
 230 students (Q1- Fig 3 - 86.8% versus 2.8%) enjoyed the use of battle in the courses and
 231 thought they were more active than in a traditional bibliographic research training
 232 session (Q2 - Fig 3 - 84.9% versus 3.7%). At INSA Toulouse, these training sessions
 233 take place yearly, with an increase in level or a focus on research/specialty over the

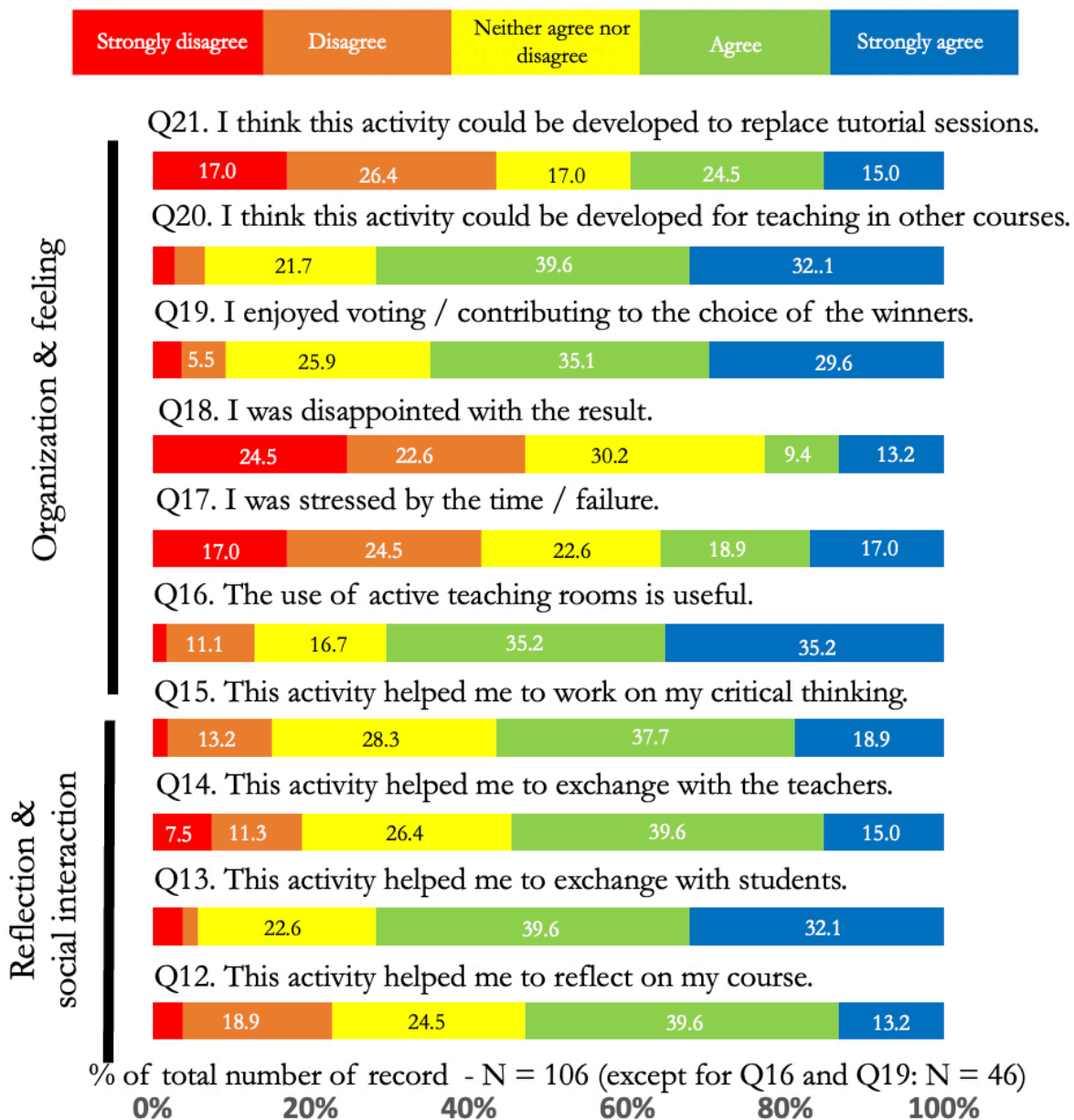
234 year. A majority of students (Q3 - Fig 3 - 71.7% versus 2.8%) thought the battle was
235 attractive and helped them to improve motivation.

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

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

260 Concerning the organization and the feeling of the students: during the last year,
261 some active rooms have been used to improve the interactions between students. These
262 rooms are designed for active teaching and have been optimized to promote group work

263 (with mobile tables and chairs and islands for groups of 6 students – Fig 2), better
264 soundproofing to absorb the noise generated by group work, excellent Wi-Fi coverage and
265 screens for each group. A large majority of the surveyed students in the last year of the
266 study (N = 46) thought the use of the active teaching room was useful for the activity
267 (70.4% - Q16 - Fig 4 - versus 12.9% - N = 46 - only surveyed in the last year). In terms of
268 feelings, 35.8% of the students' felt stressed by time or failure (versus 41.5% not stressed
269 - Q17 - Fig 4). In the free-response section of the questionnaire, some students reported
270 that they would have preferred a longer time for research and coordination and that lack
271 of time resulted in stress. Only 22.6 % of the students were disappointed by the result of
272 the battle's matches (versus 47.1% - Q18 - Fig 4). This small value could be explained by
273 the fact that a majority of 64.8% of students enjoyed voting and contributing to the choice
274 of the winners (versus 9.3% - Q19 – Fig 4 – N = 46 – only surveyed in the last year).



275

276 **Figure 4.** Student responses relating to the use of battle activity. Total number of
 277 respondents = 106 (academic years 2018/2019 and 2019/2020).
 278

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

285 **DISCUSSION**

286 Used experimentally and improved by INSA students and educators for four years
287 (2016/2017 to 2019/2020), this activity now experiences an overall positive result: (i) It
288 promotes teamwork and cooperation among students: very quickly, students understand
289 that the oral participation of all members of the group is a criterion for deciding between
290 two teams (and it could be imposed by the teacher/referees). The students who are most
291 comfortable with argumentation or who took the lead in the preparation phase take
292 advantage of the pooling phase to help the students who have the most difficulty in
293 progressing with the chemical process; (ii) It encourages the students to deepen their
294 knowledge: after the first match of the activity, some students were no longer satisfied
295 with the knowledge provided in the preparation table. They understand that the
296 additional knowledge brought will sometimes allow them to make a difference in battles.
297 They will therefore look for the most precise information; (iii) It promotes mutual listening
298 and a co-construction of skills: during the arbitration phase, the students must spot
299 errors or inaccuracies in knowledge; (iv) It facilitates the learning of knowledge because
300 it mobilizes at least 4 conditions promoting long-term information retention: (a) to have
301 understood the process to be able to apply it orally, (b) to mobilize active memorization
302 by questioning teammates, not only during the mutualization phase but also during the
303 battle phase with the opposite team, (c) to repeat the knowledge at extended intervals (2
304 matches per battle) and (d) to receive immediate feedback to rectify any misunderstanding
305 and take advantage of the error. This activity was therefore a good strategy to engage
306 students in bibliographic research training with a direct, original, and innovative
307 application session. In our format, the activity was designed for a half-day but, in view of
308 the free-response section of the questionnaire, we recommend applying it (if possible) in
309 a full-day session to give the students more time to search for information, to interact
310 with one another and to empower their communication skills. Educators need to be
311 careful about the composition of the teams and the number of team members. Too small
312 a number could lead to unbalanced teams in terms of level/leadership and too large a
313 number will lead to difficulty for students to find their place and interact. From our

314 experience, we propose an ideal number of 4-5 students per team. We also strongly
315 recommend that the educator take the time to explain the rules clearly before the session,
316 in order to explain that victory or ranking are not the goal of the session (a team can lose
317 its 2 matches even with the maximum grade A), but communication, discussion, learning
318 and fun are the only objectives.

319 The introduction of argumentative practices in science teaching profoundly modifies
320 the respective roles of the teacher and the students⁵⁷: it is no longer the authority of the
321 teacher who establishes what is true by stating what has to be learned. It is the students
322 who, through their activities, co-construct their knowledge. Working in a battle context
323 means taking risks for teachers. Their position during the battle can be destabilizing
324 because they lose the monopoly on questions and answers⁵⁸. This attitude is the opposite
325 of frontal teaching, where the teacher provides knowledge, and the questioning serves to
326 verify understanding.

327 Changing the role of the teacher is the first necessary condition for the success of the
328 battle. This raises the question of the position of the teacher in the debate. Should they
329 intervene or, on the contrary, take a back seat to encourage the progression⁵⁸ of the
330 students' questioning? A wide range of practices attempt to regulate these processes
331 without really providing any precision. It is then up to the teacher to find the level of
332 "guidance" necessary to conduct the debate⁵⁹. During the battle, teachers may act as
333 mediators and conduct the debate. Their participation should not prevent the
334 confrontation of points of view.

335 The debate is therefore regulated by the moderator who structures the session by
336 putting forward the position of the different student-debaters, by facilitating their
337 exchanges, and in some cases by trying to arbitrate conflicts. The role of the teacher is
338 to: (1) create a dynamic, tension and attention by reformulating certain divergences in
339 the form of questions, sometimes by creating doubt.... "Are you sure?"⁶⁰ (2) Coach teams
340 by encouraging them to defend their point of view by proposing a constructed argument.
341 (3) Rhythm the battle. The two teams exchange their arguments one after the other,
342 answering successive questions from the moderator in front of the audience. Speaking

343 time is limited, to stimulate exchanges and get straight to the point. The moderator is
344 therefore necessary to ensure that the rules of the game are respected. He is a referee,
345 and a successful battle is one where the participants bring the debate by themselves by
346 exploring the different aspects of their subject.

347

348 **CONCLUSION**

349

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

372 **ASSOCIATED CONTENT**

373 Tournament game scoreboard (PDF)

374 **AUTHOR INFORMATION**

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385 Note: The authors declare no competing financial interest.

386

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