RESEARCH ARTICLE

Integration of a serious game about haematology (SUPER HEMO®) in a pharmacy curriculum: A 2-year follow-up

Amélie Meeus[1] , Julien Gravoulet[1] , Julien Broséus[2,3] , Maud D'Aveni[2,3] , Julien Perrin[1,2]

[1] Faculté de Pharmacie, Université de Lorraine, Nancy, France
[2] Faculté de Médecine, Maïeutique et Métiers de la Santé, Université de Lorraine, Vandœuvre-Lès-Nancy, France
[3] Centre Hospitalier Régional Universitaire, Nancy, France

Abstract

Background: Serious Games (SG) are prevalent game-based learning approaches in healthcare education. SUPER HEMO® (SH) is a digital SG designed for healthcare students to improve their knowledge and skills in haematology. This report describes the 2-year use of SH by pharmacy students at the University of Lorraine, France. SH is completely integrated into the haematology courses through 2 different approaches: full-open access on a website, allowing students to play at will, and two mandatory game-based tutorials, providing further feedback on critical topics. **Methods:** The purpose was 1/ to evaluate knowledge acquisition following game-based tutorials by comparing pre/post-test evaluations; 2/ to collect information regarding the game's use by assessing website connections and *"daily active users"* and 3/ students' game experience by online, anonymous, voluntary survey. **Results:** Pre/post-test evaluations performed during the tutorials firmly showed that SH enables immediate knowledge acquisition. Additionally, 98% of students greatly appreciated these tutorials, especially because of the additional feedback provided. Regarding open access, website analysis revealed recurrent activity (8 daily active users on average). Finally, students appreciated this novel pedagogical tool. **Conclusion:** Overall, the real-life use of SH confirms that both open-access and game-based tutorials perfectly fit pharmacy students' needs and expectations for haematology learning.

Introduction

Gamification consists of including game elements in non-game activities to encourage motivation and engagement (Cugelman, 2013; Watsjold *et al*., 2022). For the last two decades, this has led to the increasing development of Game-Based Learning (GBL) methods (Oestreich & Guy, 2022). In higher education, Serious Games (SG) undoubtedly stand as one of the most popular and implemented GBL approaches (Brandl & Schrader, 2024). Indeed, GBL and SG allow a shift from teacher-centred and lecture-based learning to student-centred teaching, fostering deeper involvement and engagement. This transition changes students' attitudes from passive (unchallenging and sometimes boring) to active learning. Furthermore, while varied concepts are declined, such as card games, board games and platforms (Cosimini *et al*., 2022; Edwards *et al*., 2023), digital SG are among the most widely implemented, aligning with technological advancements and dissemination (Brandl & Schrader, 2024). Healthcare education has widely adopted serious games, from student teaching to patient education (van Gaalen *et al*., 2021; Wang *et al*., 2022; Xu et al., 2023; Koelewijn *et al*., 2024). In a field where mistakes and misinterpretations may have critical consequences, SGs provide a safe learning environment without direct consequences on patients. It is worth noting, however, that despite their widespread use, the practical effectiveness of SG remains a matter of debate (Gorbanev *et al*., 2018;

Maheu-Cadotte *et al*., 2021). Within healthcare studies, the pharmacy curriculum encompasses a wide range of fields, from applied sciences to medical and clinical knowledge, where the use of GBL is not new (Piascik, 2013; Cain & Piascik, 2015; Sera & Wheeler, 2017; Lee & Lee, 2021; Kanaan *et al*., 2023). In this curriculum, haematology has a substantial part since pharmacists must understand haematological concepts, especially to master the wide range of potential drug-induced variations in blood cells (such as thrombocytopenia, neutropenia...) and their consequences for patients (bleedings, infections, anaemia…) (Mintzer *et al*., 2009).

While there are a few published initiatives dealing with GBL in haematology teaching, most focus on anaemia and transfusion (Wargo, 2000; Tan *et al*., 2017; Pisano *et al*., 2020; Aloweni *et al*., 2021; Bianchi *et al*., 2022). At the University of Lorraine, the authors have developed a digital SG called SUPER HEMO® (SH) to help healthcare students improve their knowledge and skills in haematology. SUPER HEMO® is a visual novel and point-and-click serious video game about haematology. The first part (Red World, dealing with red blood cell disorders) was introduced in the previous proof-of-concept study (Perrin *et al*., 2023). Since then,

the game has been further developed with 1/ three additional parts: White World (dealing with leukocytes disorders), Yellow World (related to platelets and haemostasis disorders) and a Bonus Mystery World (with complex blood disorders) (Appendix A); 2/ improved game mechanics to be more level-inclusive.

The game's course is presented in Figure 1. Briefly, after choosing a female or a male avatar on the home screen and being explained the game's principles by their guide, "*Lady Stem Cell*", students are immersed into a dream-like world strongly related to haematology featuring elements such as red blood cell trees and blood cells stained-glass windows. They will play as a haematology superhero in training named SUPER HEMO, who will explore the above-mentioned worlds (Red, White, Yellow and Mystery worlds) to meet characters presenting haematological disorders. Players must correctly interpret CBC, answer their questions and finally find the best way to help them, regarding the potentially usable drugs especially. "*Magicians*" (haematology-biologists, pharmacists, radiologists, pathologists, and geneticists) may intervene or be summoned to help the player find the right answer in exchange for gold coins or to give feedbacks/comments.
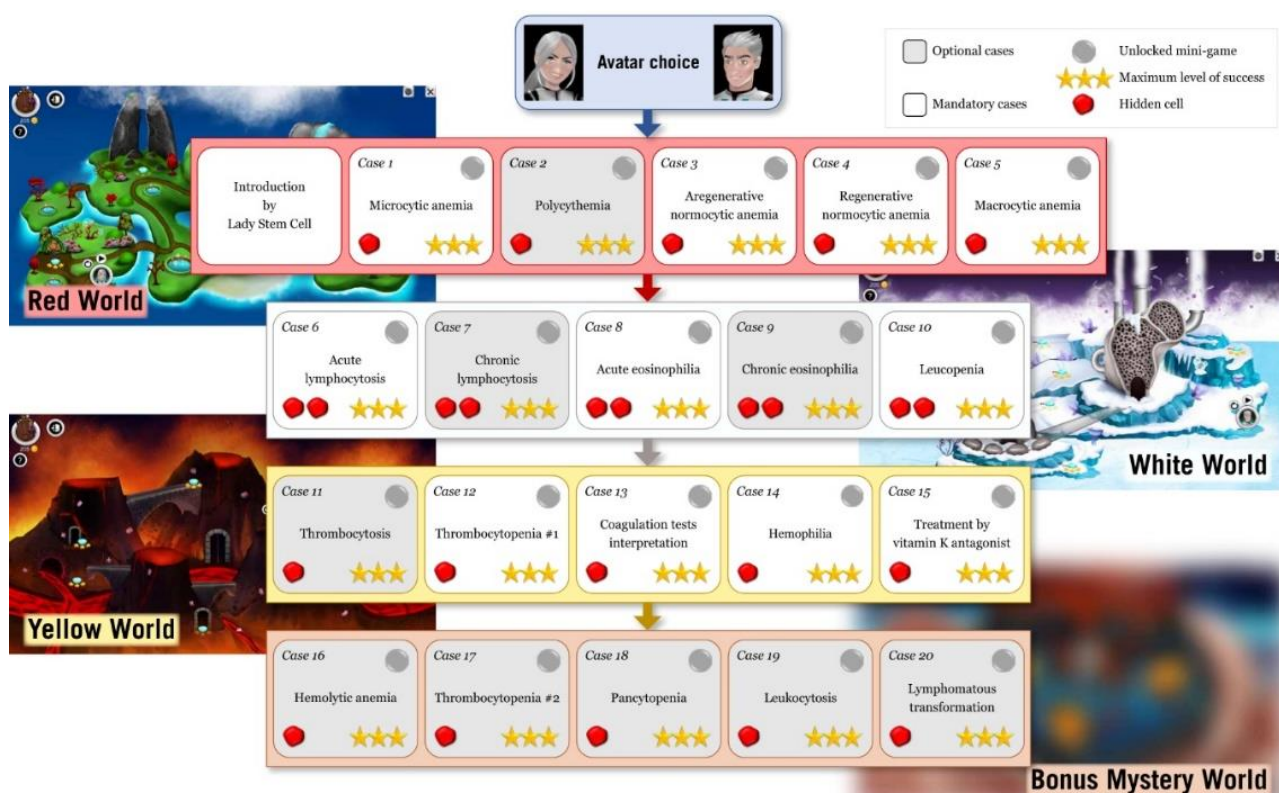

Figure 1: SUPER HEMO® diagram and progression

Each world includes five clinical cases to resolve, some of them being mandatory, others optional because they are deemed too complex for third-year students (since some topics, such as haematological malignancies, are studied in upper levels). When successfully achieving a clinical case, players are rewarded with 1, 2, or 3 stars depending on the number of errors they made. Moreover, a hidden haematopoietic cell can be caught, and a mini-game is unlocked to earn extra gold coins, which are necessary to solve more cases. In addition, patients' trust is impaired after a wrong answer to a skill or treatment question. Brief and immediate feedback may be given by Lady Stem Cell or Magicians. If all gold coins or the patient's trust is lost, the player moves back to the beginning of the case to immediately play again if they have enough gold coins; otherwise, they can still earn gold coins in mini-games before trying the case again. The hidden collected cells constitute an atlas of haematopoietic cells that contain the description and a picture of the cells. Mini-games are always related to haematology in a fun way. When players achieve all mandatory cases and reach 80% success (i.e. 12 stars out of a possible 15), they can move on to the next world. The concept of SUPER HEMO®, as well as its relevance, have been previously validated among undergraduate medical and pharmacy students (Perrin *et al.*, 2023). Then, the game's development has been achieved, allowing its full integration since 2022 into the pharmacy curriculum within the traditional haematology courses. This report describes the 2-years experience (2022 and 2023) following SH integration into the pharmacy curriculum at the University of Lorraine.

Methods

Design

This is an observational study presenting the implementation, since 2022, of SUPER HEMO®'s full version within the pharmacy curriculum at the University of Lorraine. The purpose was 1/ to evaluate knowledge acquisition following game-based tutorials; 2/ to collect information regarding game's use and 3/ students' game experience.

The study was supervised by Julien Perrin, a haematology teacher at the faculty of pharmacy, who managed the tutorial sessions and Amélie Meeus, an educational engineer, who wrote the surveys and collected data. Data and results were analysed and discussed within the scientific committee (Maud D'Aveni-Piney, Julien Gravoulet, Julien Broséus, and Amélie Meeus and Julien Perrin).

Students

The study enrolled all the students from the third-year of the pharmacy curriculum (where haematology courses are held) at the University of Lorraine in 2022-23 (year #1, N=137) and 2023-24 (year #2, N=117).

Integration of SUPER HEMO® into haematology courses

Haematology teaching unit is composed of lecture-based courses, two tutorial sessions and two practical work sessions.

Since September 2022, SUPER HEMO® is freely available on the University of Lorraine-hosted website for all students with their ID and password (https://super-hemo.univ-lorraine.fr/). Accordingly, they can access it at will. Within the traditional lecture-based haematology course for the third-year undergraduate pharmacy students, open access to the SH website was concomitantly implemented, as well as two mandatory game-based tutorials involving small groups (5 groups of around 25 students per group every year), so that overall, 254 students (137 for year #1 and 117 for year #2) were enrolled in tutorials.

These sessions (90 min) were organised as follows:
• Presentation of the session objectives
• Pre-test evaluation
• Game session (approximately 45-60 minutes)
• Post-test evaluation
• Feedback on key-lesson points

Session #1 was dedicated to anaemias and red blood cell disorders (centred on the Red World), while session #2 addressed abnormal leucocytes or platelets counts (centred on the White and Yellow Worlds, respectively). On average, 2 weeks separated both sessions per group.

Assessment of knowledge acquisition

Immediate knowledge acquisition was assessed by comparing pre/post-test evaluations, consisting of a knowledge test with 10 multiple-choice questions. One point was awarded for each correct answer. In order to estimate mid-term knowledge retention, two questions from Session #1 on anaemias were included in the pre and post-tests for Session #2. Scores of pre- vs post-tests were expressed as median values, with ranges and 25–75 percentiles. Individual progression was determined by calculating the difference (termed Δ) between post-test and pre-test scores. Scores were compared using a paired Wilcoxon signed-rank test, and Spearman's rank test was used for correlation tests. Statistical analysis was performed using PRISM® V5.0.

Open access assessment

To evaluate the student use of SUPER HEMO® beyond the integrated sessions, website connections and "*daily active users*" (defined as the number of different players starting a session on a given day) were assessed using Unity Analytics® throughout the haematology course period (from the first lecture to the final exam, approximately 2.5 months).

Game and gameplay evaluation

At the end of the first semesters of 2022 and 2023, students were surveyed online - on a voluntary basis and anonymously - about their overall experience with SUPER HEMO®. The survey was divided into four parts: perception of haematology, free access to the game, game experience, and tutorial experience; 202 students answered the survey across both cohorts (response rate: 79.5% of the entire population), some responses being however incomplete.

Ethics approval

According to French laws (CSP Article L1121-1, Article R1121-1-II2), the project does not require a statement of the ethics committee, namely "*Comité de Protection des Personnes*". The project has been, however, accepted by both Pedagogic Committee and Board of the Faculty of Pharmacy. In addition, information to students was given as follows:

- before each tutorial, oral information regarding data collection was also given to students.

- when connecting to the game's website, the following information regarding data collection is given (see Appendix B and translated below) "*The application*

collects usage data for statistical study purposes. This data is anonymised, but it is possible to deactivate. This functionality in the options"; The player has to click "*I understand*" before playing or change the options if required.

Results

All results being similar between both years (data not shown), the following data encompass the entire population (i.e. 254 students).

Assessment of knowledge acquisition

Median post-test scores were significantly improved compared to pre-tests ($p < 0.001$), with 2 points higher median scores (Figure 2), from 6.1 to 8.2 and from 6.3 to 8.1, for sessions #1 and #2, respectively. Furthermore, post-test results showed tightened ranges and dispersion, indicating overall knowledge improvement and homogenisation. At the individual level, 82% and 84% of students obtained higher scores in sessions #1 and #2, respectively. A significant correlation was observed between pre-test scores and progression Δ (r Spearman -0.70, $p < 0.001$; -0.65, $p < 0.001$ for session #1 and #2, respectively), suggesting that students with the lowest pre-test scores displayed the most progress (Figure 2). Finally, for the two similar questions asked in sessions #1 and #2, 85% and 79% of students answered correctly for Q1 and Q2, respectively, in the pre-test of session #2, while they were 56% and 63% only in the pre-test of session #1 for Q1 and Q2, respectively.
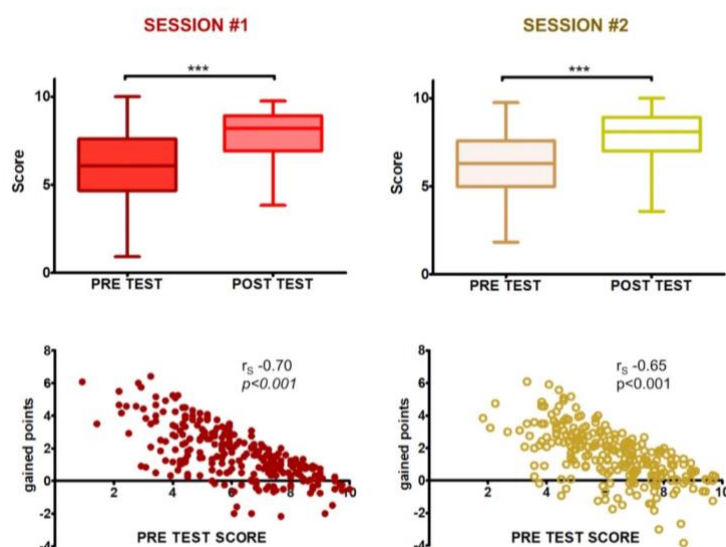

Figure 2: Results pre-and post-tests and correlation with progression from the two game-based tutorials; session #1: anaemia; session #2: leukocytes and platelets disorders

Open access assessment

Website connection data (Figure 3) revealed daily activity throughout the haematology course period, with an average of 8.5 daily active users; of note, peaks in connections were observed a few days before final exams.
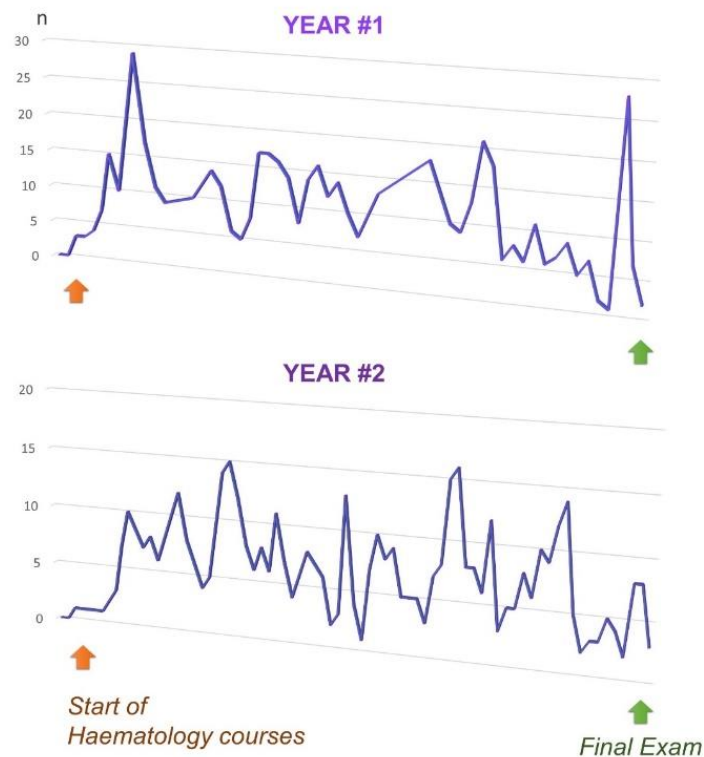

Figure 3: Daily active users all along from the duration of haematology courses (around 2.5 months)

Game and gameplay evaluation

Concerning the questionnaire, it received 202 answers (some incomplete) from students across both cohorts (79.5% of the entire population); all results are presented in Appendix C.

Perception of haematology

All respondents except one considered haematology an interesting topic, with over 80% (N=166) believing it would have a significant impact on their future professional practice. While 72% (N=145) found haematology neither difficult nor easy, learning haematology was considered harder than understanding: 60% stated difficulty to learn haematology, but only 15% stated difficulty to understand.

Open Access to SUPER HEMO®

Eighty-six percent (N=172) of respondents played the serious game outside tutorial times, while the rest (N=27) were aware of its availability. Eighty-eight percent (N=175) discussed SUPER HEMO® with classmates focusing on form (59%) and content (57%), encouraging others to play (40%) or being encouraged themselves (11%).

Among the students who played SUPER HEMO®, playtime goes from less than an hour to more than 5 hours, with an average time between 1 and 3 hours (the three main parts are meant to last around 3 hours) and one-fourth of the students playing between 3 and 5 hours. Concerning the in-game progress, almost 50% completed two-third of the game (Red and White Worlds finished), and 10% finished the three main parts and completed their progress by looking for hidden cells and/or completing the cases of the Bonus World (Figure 4).
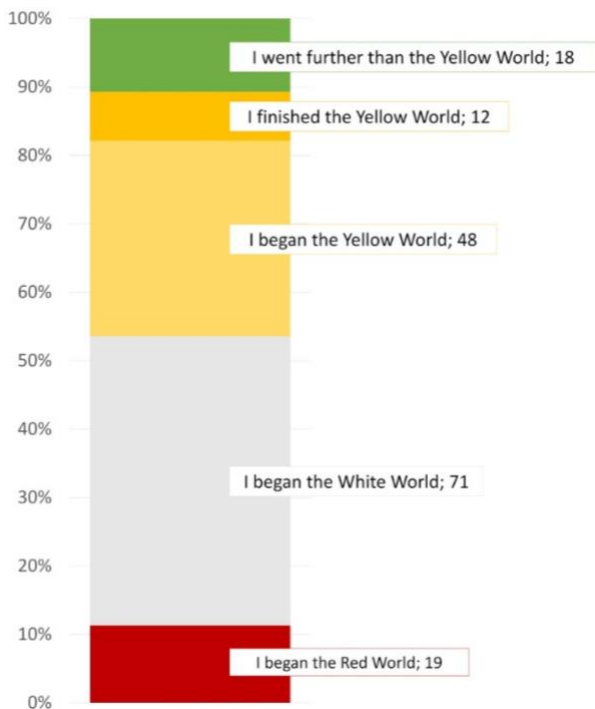
Figure 4: In-game progress

Game experience

Overall, SUPER HEMO® is very well received by pharmacy students (Figure 5). Several goals that players might aim for were identified: finishing all cases, winning all stars, finding all hidden cells and playing mini-games. Almost 75% wanted to finish all the cases, and more than 60% wanted to win as many stars as possible; 56.5% had the goal to play the mini-games, but less than half of the students tried to find every hidden cell. As for their experience, almost two-thirds enjoyed playing, less than 2% gave up, and 3% did not understand the link between SH and the lessons. Ninety percent learned from their playtime, and more than seventy percent used it to study before their exams. SUPER HEMO® is mainly intended for third-year health students, and more than 75% of the third-year pharmacy students confirmed that the complexity is well suited to them. More than 90% learned from it, 90% made progress in haematology, 87% understand better haematology after playing the SG, and more than 80% improved their ability to read CBC.
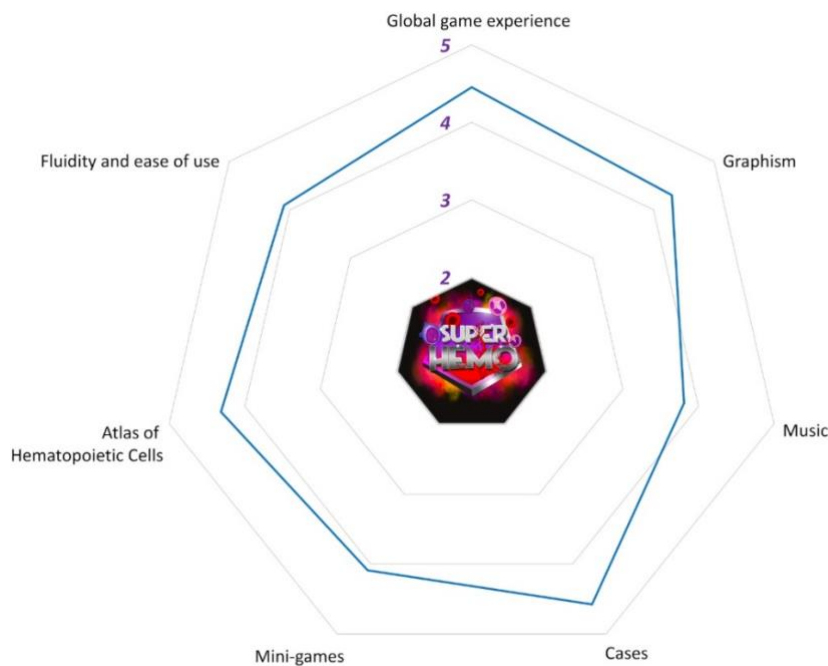
Figure 5: Students' perception of SUPER HEMO®

Tutorial experience

Most students (95%) learned about SUPER HEMO® in class, leading over 75% to play after the first tutorial. However, 20% played before. Among 189 respondents, only 4 (2%) did not think that using the serious game during the tutorial was better than a regular tutorial. All tutorial components were highly rated 4.4 out of 5 (whole session, use of SG in class, link between game

and lesson) and 4.6/5 (debriefing). Students' tutorial experience is diverse. Half of the students exchanged answers during playtime, more than 85% learned from tutorials, and 72% appreciated debriefings with a teacher. Only one student did not understand the link between lessons and game-based tutorials.

Discussion

This study aimed at assessing 1/how SUPER HEMO® allows knowledge acquisition, 2/if (and how) students use the game for haematology learning and 3/how they perceive this novel educational tool.

Strikingly, all the collected data (results, connections and evaluation surveys) were very similar between both years, indicating a recurrent positive global impact of the game.

First, regarding mandatory tutorials, the results firmly confirm that playing SH during these sessions allows the acquisition of immediate knowledge, as evidenced in the initial evaluation of the game (Perrin *et al*., 2023). In fact, regardless of the field offered (Red, White or Yellow World, corresponding to RBCs, leucocytes or platelets/haemostasis disorders, respectively), a significant achievement was observed in the pre-/post-tests evaluation. Furthermore, there was a significant correlation between the pre-test score and the gained points in the post-test: this illustrates that a game session allows helping both the weakest students as well as the best students (with a high pre-test score > 8) who may further progress. In parallel, data also showed a better rate of correct answers to previously asked questions between sessions #1 and #2. Nevertheless, although encouraging, these results are clearly insufficient to firmly assess mid-term knowledge retention.

These tutorials - where all students (in small groups) play the same definite cases - allow the discussion on specific and critical themes with a debriefing on key points after the playing period. Interestingly, while intrinsic feedback, a critical point for the effectiveness of game-based learning (Singhal *et al*., 2016; Watsjold *et al.,* 2022), is integrated within the progression, students highlighted the importance of the additional feedback and final debriefing given during these sessions ("*Better understanding because the game gives us an explanation when we make mistakes and if we still do not understand, we can always ask the teacher for clarifications*" - original comments in French, translated). Furthermore, they expressed their preference for this format over traditional sessions ("*We study the same things but with a different angle and it helps a lot*"; "*A*

tutorial in which I paid close attention during the 1.5 hour"). As a student wrote, "*these tutorials are essential*" because the debriefing allowed students to clarify difficulties. Indeed, debriefing stands as a particular, post-event form of feedback, very common in healthcare innovative educational tools, helping the students learn from the game experience (Motola *et al*., 2013).

Parallel to these game-based tutorials, SUPER HEMO® is, above all, freely available online to students, offering voluntary participation, another key feature for effective serious games (Watsjold *et al*., 2022; Wang *et al*., 2022). Analysis of the website's connections shows regular engagement and, interestingly, additional connection peaks near exams, illustrating that some students included the game in their final revisions. This is consistent with the comments collected in the final survey ("*I have a lot of friends that told me they played at night: it allowed them to review while having the feeling to play*"; "*I really liked playing SUPER HEMO because it allows us to review in a simple manner because haematology is hard to learn with the sole course*"). Finally, this corroborates the relevance of choice for "*open access*".

Overall, SUPER HEMO® is well-accepted, used for lesson reviews, and encourages peer interaction, and this is illustrated by the high participation rate (nearly 80%). This may be because students recognise haematology's place in their curriculum as well; indeed, more than 75% considered haematology to be important for their future professional practice. However, they find it challenging, as reflected by the comments: "*Perfect, helps a lot with learning*"; "*Thanks for creating this game to help us have better understanding of a subject that can be hard to learn*"; "*Great project created to make us learn and like haematology*". In this context, innovative pedagogical tools like serious games are particularly relevant, making learning more engaging and motivating by providing a different insight than the traditional course and making students immersed and involved in the field while playing, allowing them to reach educational goals (Cugelman, 2013; Singhal *et al*., 2016; Watsjold *et al*., 2022). In addition, this encompasses the adaptation of learning methods to generational considerations since today's learners are more prone to use technology [Pick *et al*., 2017].

This report, as a two-year inventory of SUPER HEMO® use, has limitations. First, the quality of evidence on a serious game's effectiveness is a recurrent issue - in healthcare especially (Gorbanev *et al*., 2018; Xu *et al*., 2023) - pre/post-test evaluations only assess immediate knowledge acquisition, whereas long-term retention should be preferred (Cugelman, 2013; Maheu-Cadotte *et al*., 2021). A two-group comparison would better assess the game's impact, but randomising students post-

pandemic is challenging since it has upset habits and teaching. Indeed, it would have been difficult to randomly choose students who could not try or benefit from this novel pedagogical material. Second, another limitation is that behavioural changes, an added value of SG (Hammady & Arnab, 2022), were not evaluated.

Conclusion

Keeping in mind that SUPER HEMO® by itself does not intend to replace lectures or tutorials, it really stands as an additional tool used to enhance students' engagement and motivation, consistently with the view that blended teaching methods improve learning (Lee & Lee, 2021). Overall, consistent results between years indicate a lasting positive impact of SUPER HEMO® on students' knowledge acquisition and satisfaction.

Conflict of interest

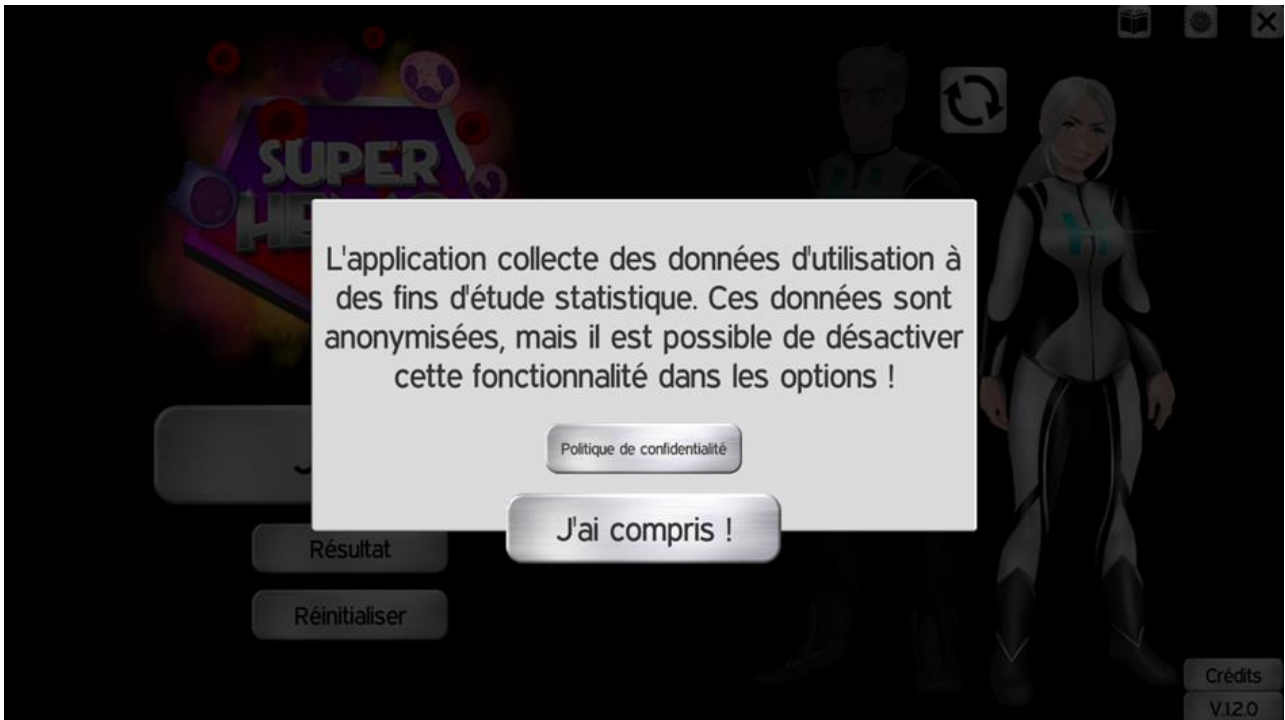The authors declare no conflict of interest.

Source of funding

References

Aloweni, F., See, M. T. A., Ng, X. P., & Ang, S. Y. (2021). Employing serious game for assessing knowledge of blood transfusion procedure mong nurses: A qualitative evaluation and feedback improvement study. *Nurse Education Today*, **101**, 104873. https://doi.org/10.1016/j.nedt.2021.104873.

Bianchi, I., Stefani, C. J. M., Santiago, P., Zanatta, A. L., & Riede, R. (2022). AnaemiaAR: A serious game to support teaching of haematology. *Journal of Visual Communication in Medicine*, **45**(3), 134–153. https://doi.org/10.1080/17453054.2021.2021798.

Brandl, L. C., & Schrader, A. (2024). Serious games in higher education in the transforming process to education 4.0—Systematized review. *Education Sciences*, 2024, **14**(3), 281. https://doi.org/10.3390/educsci14030281

Cain, J., & Piascik, P. (2015). Are serious games a good strategy for pharmacy education? *American Journal of*

Pharmaceutical Education, **79**(4), 47. https://doi.org/10.5688/ajpe79447

Cosimini, M. J., Watsjold, B., & Chan, T. M. (2022). Serious games without screens. Comment on "Involvement of end users in the de-velopment of serious games for health care professions education: Systematic descriptive review". *JMIR Serious Games*, **10**(1), e34656. https://doi.org/10.2196/34656

Cugelman, B. (2013). Gamification: What it is and why it matters to digital health behavior change developers. *JMIR Serious Games*, **1**(1), e3. https://doi.org/10.2196/games.3139

Edwards, S., Swamy, L., Cosimini, M., Watsjold, B., & Chan, T. M. (2023). Educator's blueprint: A how-to guide for creating analog serious games for learning in medical education. *AEM Education and Training*, **7**(6), e10907. https://doi.org/10.1002/aet2.10907

Gorbanev, I., Agudelo-Londoño, S., González, R. A., Cortes, A., Pomares, A., Delgadillo, V., Yepes, F. J., & Muñoz, Ó. (2018). A systematic review of serious games in medical education: quality of evidence and pedagogical strategy. *Medical Education Online*, **23**(1), 1438718. https://doi.org/10.1080/10872981.2018.1438718

Hammady, R., & Arnab, S. (2022). Serious gaming for behaviour change: A systematic review. *Information*, **13**(3), 142. https://doi.org/10.3390/info13030142

Kanaan, S., Dabbous, M., Akel, M., Lteif, R., Rahal, M., & Sakr, F. (2023). Game-based learning in pharmacy education: A systematic review and narrative synthesis. *Pharmacy Education*, **23**(1), 629–639. https://doi.org/10.46542/pe.2023.231.629639

Koelewijn, G., Hennus, M. P., Kort, H. S. M., Frenkel, J., & van Houwelingen, T. (2024). Games to support teaching clinical reasoning in health professions education: A scoping review. *Medical Education Online*, **29**(1), 2316971. https://doi.org/10.1080/10872981.2024.2316971

Lee, C. Y., & Lee, S. W. H. (2021). Impact of the educational technology use in undergraduate pharmacy teaching and learning – A systematic review. *Pharmacy Education*, **21**, 159–168. https://doi.org/10.46542/pe.2021.211.159168

Maheu-Cadotte, M. A., Cossette, S., Dubé, V., Fontaine, G., Lavallée, A., Lavoie, P., Mailhot, T., & Deschênes, M. F. (2021). Efficacy of serious games in healthcare professions education: A systematic review and meta-analysis. *Simulation in Healthcare: The Journal of the Society for Simulation in Healthcare*, **16**(3), 199–212. https://doi.org/10.1097/SIH.0000000000000512

Mintzer, D., Billet, S. N., & Chmielewski, L. (2009). Drug-induced hematologic syndromes. *Advances in Hematology*, **2009**, 495863. https://doi.org/10.1155/2009/495863

Motola, I., Devine, L. A., Chung, H. S., Sullivan, J. E., &Issenberg, S. B. (2013). Simulation in healthcare education: a best evidence practical guide. AMEE Guide No. 82. *Medical Teacher*, **35**(10), e1511–30. https://doi.org/10.3109/0142159X.2013.818632

Oestreich, J. H., & Guy, J. W. (2022). Game-based learning in pharmacy education. *Pharmacy (Basel)*, **10**(1), 11. https://doi.org/10.3390/pharmacy10010011

Perrin, J., Meeus, A., Broseus, J., Morieux, P. J., Di Ceglie, V., Gravoulet, J., & D'Aveni, M. (2023). A serious game about haematology for health care workers (SUPER HEMO): Development and validation study. *JMIR Serious Games*, **11**, e40350. https://doi.org/10.2196/40350

Piascik, P. (2013). CAPE outcomes 2013: Building on two decades of advances to guide the future of pharmacy education. *American Journal of Pharmaceutical Education*, **77**(8), 160. https://doi.org/10.5688/ajpe778160

Pick, A. M., Begley, K. J., & Augustine, S. (2017). Changes in teaching strategies to accommodate a new generation of learner: A case study. *Pharmacy Education*, **17**. https://pharmacyeducation.fip.org/pharmacyeducation/article/view/455

Pisano, T. J., Santibanez, V., Hernandez, M., Patel, D., &Osorio, G. (2020). The bloody board game: A game-based approach for learning high-value care principles in the setting of anaemia diagnosis. *MedEdPORTAL: The Journal of Teaching and Learning Resources*, **16**, 11057. https://doi.org/10.15766/mep_2374-8265.11057

Sera, L., & Wheeler, E. (2017). Game on: The gamification of the pharmacy classroom. *Currents in Pharmacy Teaching and Learning*, **9**(1), 155–159. https://doi.org/10.1016/j.cptl.2016.08.046.

Singhal, S., Hough, J., & Cripps, D. (2019). Twelve tips for incorporating gamification into medical education. *MedEdPublish (2016)*, **8**, 216. https://doi.org/10.15694/mep.2019.000216.1

Tan, A. J. Q., Lee, C. C. S., Lin, P. Y., Cooper, S., Lau, L. S. T., Chua, W. L., & Liaw, S. Y. (2017). Designing and evaluating the effectiveness of a serious game for safe administration of blood transfusion: A randomized controlled trial. *Nurse Education Today*, **55**, 38–44. https://doi.org/10.1016/j.nedt.2017.04.027

van Gaalen, A. E. J., Brouwer, J., Schönrock-Adema, J., Bouwkamp-Timmer, T., Jaarsma, A. D. C., & Georgiadis, J. R. (2021). Gamification of health professions education: A systematic review. *Advances in Health Sciences Education*, **26**(2), 683–711. https://doi.org/10.1007/s10459-020-10000-3

Wang, Y., Wang, Z., Liu, G., Wang, Z., Wang, Q., Yan, Y., Wang, J., Zhu, Y., Gao, W., Kan, X., Zhang, Z., Jia, L., & Pang, X. (2022). Application of serious games in health care: Scoping review and bibliometric analysis. *Front Public Health*, **10**, 896974. https://doi.org/10.3389/fpubh.2022.896974

Wargo, C. A. (2000). Blood Clot: Gaming to reinforce learning about disseminated intravascular coagulation. *he Journal of Continuing Education in Nursing*, **31**(4), 149–51. https://doi.org/10.3928/0022-0124-20000701-04

Watsjold, B. K., Cosimini, M., Mui, P., & Chan, T. M. (2022). Much ado about gaming: An educator's guide to serious games and gamification in medical education. *AEM Education and Training*, **6**(4), e10794. https://doi.org/10.1002/aet2.10794

Xu, M., Luo, Y., Zhang, Y., Xia, R., Qian, H., & Zou, X. (2023). Game-based learning in medical education. *Frontiers in Public Health*, **11**, 1113682. https://doi.org/10.3389/fpubh.2023.1113682

Appendix A: Screenshots of SUPER HEMO®
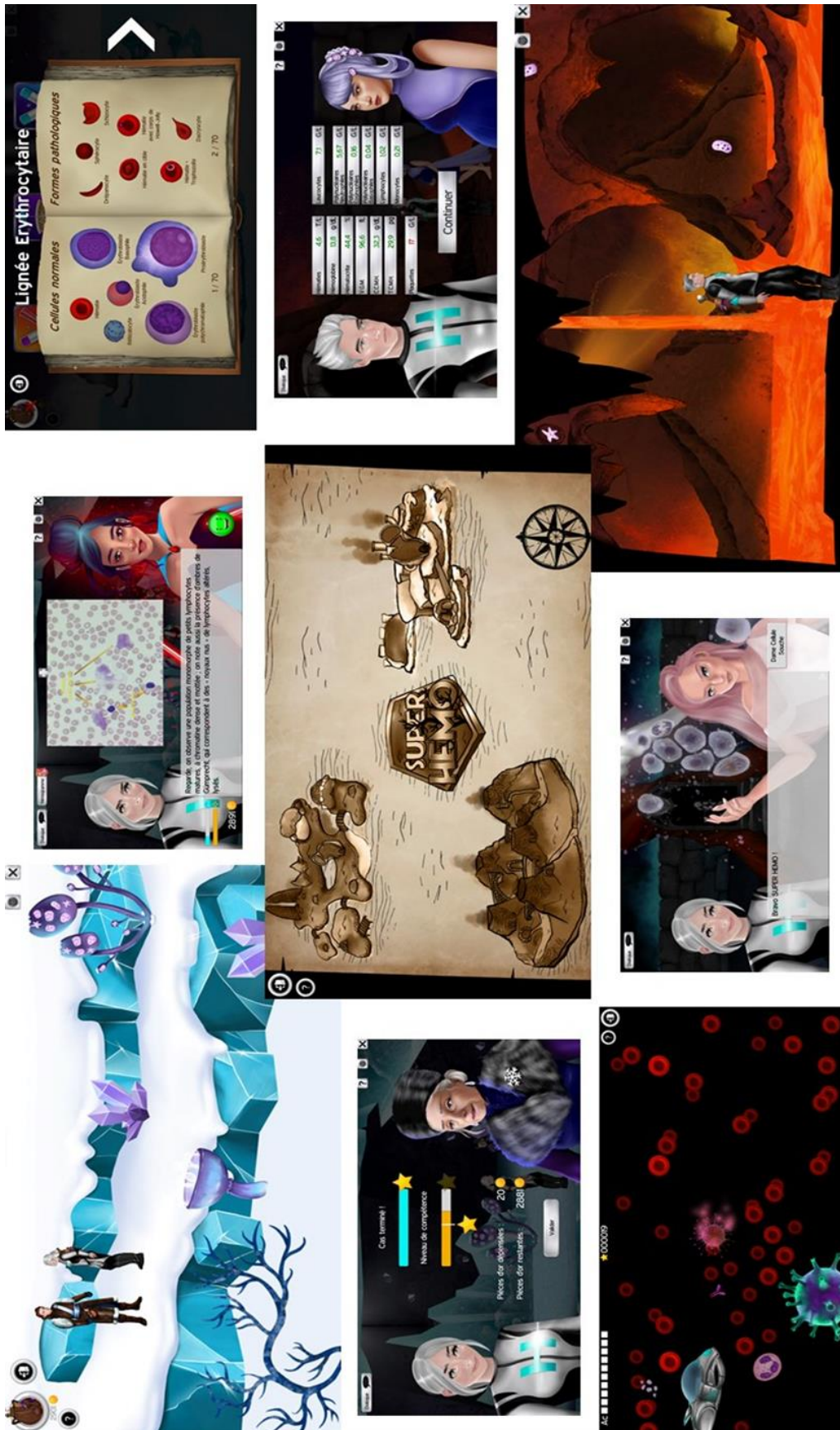
Appendix B: Information on data collection

Appendix C: Online survey regarding overall game experience (202 answers–some incomplete)

Haematology and you	**According to you, how interesting is haematology as a study subject?**	Not interesting at all	Not interesting	Neutral	Interesting	Very interesting
		0%	0%	0.5%	25%	74.5%
	From a general perspective, how do you feel about studying haematology?	Very easy	Easy	Easy Intermediate	Hard	Very hard
		1%	14%	72%	13%	0%
	Would you say that haematology is a subject… *[multiple answers possible]*	Hard to understand	Hard to learn	Easy to understand	Easy to learn	None of the above
		N=25	N=91	N=138	N=60	N=10
	According to you, how important will haematology be as a health professional?	Not important at all	Not important	Neither	Important	Very important
		1%	4%	13%	52%	30%

Free access to the serious game SUPER HEMO®	**Did you play SUPER HEMO® (outside of the mandatory lessons)?**	Yes	No			
		86%	14%			
	Did you know that SUPER HEMO® existed and that you could access freely?	Yes	No			
		100%	0%			
	How did you learn about SUPER HEMO®?	A teacher mentioned it in class	A teacher mentioned it during the meeting at the beginning of the year	On the screens at the Faculty	I read the article on the Faculty journal	I saw the online course related to it
		69%	3%	8%	1%	12%
	Did you talk to your classmates about SUPER HEMO®?	Yes	No			
		88%	12%			
	If "yes", what about? *[multiple answers possible]*	You talked about the scientific content (solving the cases).	You talked about the game aspects (mini-games, hidden cells…).	You encouraged them to play.	They encouraged you to play.	Other
		N=118	N=113	N=79	N=23	/

Game experience	**How long do you think you spent playing (outside of mandatory lessons)?**	> 1h	Between 1h and 3h	Between 3h and 5h	< 5h		
		16%	47%	25%	13%		
	How far did you go?	I started the Red World	I finished the Red World and started the White World	I finished the White World and started the Yellow World	I finished the Yellow World	I finished the game (finished all three Worlds and found the hidden cells)	
		11%	42%	29%	7%	11%	
	In general, from 1 to 5, how would you mark SUPER HEMO®? (1 = minimum ; 5 = maximum).	1	2	3	4	5	Mean
		N=0	N=0	N=4	N=84	N=90	*4.40*
	Mark the following elements (1 = minimum ; 5 = maximum).	1	2	3	4	5	Mean
	Graphisms (characters, maps, landscapes, interface…)	N=0	N=4	N=14	N=26	N=28	*4.08*
	Music	N=4	N=6	N=23	N=19	N=20	*3.63*
	Cases	N=0	N=0	N=2	N=25	N=45	*4.60*
	Mini-games	N=0	N=5	N=14	N=31	N=22	*3.97*

Atlas of blood cells	N=0	N=1	N=15	N=27	N=29	**4.17**
Fluidity et ease of game navigation	N=0	N=2	N=15	N=27	N=28	**4.13**

Which sentences represent your experience? *[multiple answers possible]*	I got bored	I did not understand how to play	I had fun	I had fun I strengthened my knowledge thanks to the game	I gave up	I did not understand the link between the lesson and the game	I used the game to revise
	N=0	N=1	N=105	N=152	N=3	N=5	N=120

When playing you wanted to:	Not at all	No	Neutral	Yes	Yes absolutely
Finish every case	N=10	N=11	N=23	N=37	N=16
Find every hidden cell	N=27	N=26	N=40	N=40	N=35
Play mini-games	N=8	N=25	N=40	N=73	N=22
Win every star	N=12	N=16	N=37	N=61	N=43

Learning	Not at all	No	Neutral	Yes	Yes absolutely
I developed my knowledge thanks to the game.	N=0	N=4	N=11	N=85	N=68
I believe I made progress in haematology thanks to the game.	N=0	N=2	N=15	N=86	N=65
The game helped me better understand the haematology lessons.	N=1	N=2	N=18	N=87	N=34
I made progress in reading a Complete Blood Count thanks to the game.	N=3	N=5	N=21	N=61	N=78

How difficult did you think the game is?	Too easy	Easy	Well suited	Difficult	Too difficult
	0%	2%	80%	18%	0%

Tutorials						
Did you play SUPER HEMO® before the first tutorial?	Yes	No				
	21%	79%				
Did you play on your own between or after tutorials?	Yes	No				
	79%	21%				
In general, from 1 to 5, how would you mark the two tutorials?	1	2	3	4	5	Mean
	N=0	N=2	N=16	N=72	N=99	**4.4**
From 1 to 5, how would you mark the following elements?	1	2	3	4	5	Mean
Using SUPER HEMO® during a tutorial	N=2	N=3	N=23	N=62	N=99	**4.3**
Knowledge debrief during/after play time	N=1	N=0	N=14	N=49	N=125	**4.6**
Link between knowledge and game	N=1	N=2	N=20	N=55	N=111	**4.4**
Which sentences describe your experience? *[multiple answers possible]*	I discussed with my classmates and exchanged answers while playing.	I learned more thanks to the game and the debrief.	I did not understand the link between the lesson and the game.	I enjoyed having a debrief after playing the game.		
	N=69	N=169	N=1	N=139		
Do you think that playing SUPER HEMO® and having a debrief with the teacher is more relevant than a "traditional" tutorial?	Yes	No				
	98%	2%				
What did it bring to you and why?						
Write here if you have any comments about the tutorials.						