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ABSTRACT

Introduction: Digital health programs are urgently needed to accelerate the adoption of Artificial Intelligence and Clinical Decision Support Systems (AI-CDSS) in clinical settings. However, such programs are still lacking for undergraduate medical students, and new approaches are required to prepare them for the arrival of new and unknown technologies. At University Paris Cité medical school, we designed an innovative program to develop the digital health critical thinking of undergraduate medical students that consisted of putting medical students in AI-CDSS designers' shoes.
Methods: We followed the six steps of Kern's approach for curriculum development: identification of needs, definition of objectives, design of an educational strategy, implementation, development of an assessment and design of program evaluation.
Results: A stand-alone and elective AI-CDSS program was implemented for fourth-year medical students. Each session was designed from an AI-CDSS designer viewpoint, with theoretical and practical teaching and brainstorming time on a project that consisted of designing an AI-CDSS in small groups. From 2021 to 2022, 15 students were enrolled: they rated the program 4.4/5, and 80% recommended it. Seventy-four percent considered that they had acquired new skills useful for clinical practice, and 66% felt more confident with technologies. The AI-CDSS program aroused great enthusiasm and strong engagement of students: 8 designed an AI-CDSS and wrote two scientific 5-page articles presented at the Medical Informatics Europe conference; 4 students were involved in a CDSS research project; 2 students asked for a hospital internship in digital health; and 1 decided to pursue PhD training.
Discussion: Putting students in AI-CDSS designers' shoes seemed to be a fruitful and innovative strategy to develop digital health skills and critical thinking toward AI technologies. We expect that such programs could help future doctors work in rapidly evolving digitalized environments and position themselves as key leaders in digital health.

Abbreviations: AI, Artificial Intelligence; CDSS, Clinical Decision Support Systems; AI-CDSS, Artificial Intelligence - Clinical Decision Support Systems; EHR, Electronic Health Records.

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1. Introduction

Developing digital health training is a priority for the World Health Organization (global strategy plan 2020-2025) [1], as artificial intelligence and technologies will be part of clinical practice in the future [2]. Such training is essential for helping health professionals feel confident about using technologies and working in a digitalized health system [3–5] and for encouraging them to drive the ongoing digital transformation of health care [6].

The need for digital health training was highlighted by the deans of 25 European medical schools in 2019 [7] and was supported by large-scale initiatives [8,9]. Additional graduate degrees have been introduced, especially in the U.S. [10,11], but regular digital health programs adapted to undergraduate medical students are still lacking in most medical schools [12,13]. A recent scoping review (13) showed that most programs have been implemented in the U.S. and targeted first-to-third-year medical students. Most are elective (13), and the themes are very heterogeneous [13–15], ranging from core knowledge in medical informatics to applied skills in mobile health, telehealth, computer literacy, the internet of things, and/or computer programming. These programs follow three distinct approaches:

- The *theoretical approach* consists of teaching the basics of medical informatics and/or computer science [16,17]; e.g., in the U.S., the State University of New York implemented a curriculum on computer basics and literacy for first-year medical students [17].
- The *practical approach with clinical scenarios to solve* consists of training students to use technologies with real-life scenarios. For example, in France, the Universities of Rennes and Rouen provided courses on information and communication technology using a problem-based learning method [18]; in the U.S., the University of Chicago [19] trained second-year students in electronic health records (EHRs) using a group-observed structured clinical examination, and the University of Minnesota [20] and the Oregon Health & Science University [21] proposed EHR simulation.
- The *computer programming approach* that consists of providing basic skills in computer coding [22,23]; e.g., in Canada, the University of Toronto [23] implemented a certificate course on the basics of programming.

These approaches aimed to improve students' knowledge of current technologies for specific situations. However, digital health is rapidly changing with a significant risk that acquired knowledge will quickly become outdated or even useless in the near future. Therefore, there is a need to develop new approaches to anticipate and prepare medical students for the arrival of new, fast-changing technologies [24,25].

For this purpose, the Université Paris Cité medical school experimented with an innovative training method that consisted of developing the "digital health critical thinking" of undergraduate medical students. More precisely, instead of passively transferring knowledge on specific technologies, we aimed to develop critical thinking toward technologies with two complementary axes, i.e., clinical and medical informatics. We assumed that this framework would provide students the flexibility and suitability needed to cope with the arrival of new and still unknown technologies. In our approach, medical students take the role of health informatics experts and are encouraged to solve medical informatics issues to improve clinical practice. This should enable them to develop "digital critical thinking" as well as an innovation spirit by making learning more fun and engaging and giving them basic skills to become potential future key leaders of digital health.

We applied this approach in the areas of Artificial Intelligence (AI) and Clinical Decision Support System (CDSS) and implemented a program named AI-CDSS that consisted of putting undergraduate medical students in AI-CDSS designers' shoes. Here, we describe the design, implementation and evaluation of this pilot program.

2. Methods

The design of the "AI-CDSS" program was inspired by the 6 steps of Kern's approach to curriculum development [20,26,27].

2.1. Step 1: Identifying the problem/needs

Medical schools have to comply with national programs and make decisions about the time allocated to each area of medicine, with the ambition of covering a maximum of medical skills.

Despite digital health is now part of the French national medical education program, the time allocated for digital health is almost nonexistent in most French medical schools. In this context, the Université Paris Cité has been a pioneer in France by allocating 10 h for digital health as mandatory courses in the fourth year of medicine. These 10 h are split into 3 lectures and cover large themes such as telehealth, health management systems, data, AI, mobile health, digital, information literacy, CDSS, and cybersecurity. However, it remains insufficient to cover all the medical skills required in digital health, and additional courses are needed.

To overcome this issue, we implemented an additional program as part of the "elective courses", offered by the university to fourth-year medical students. We decided to focus the program on AI-CDSS because it is meaningful and useful for clinical practice.

2.2. Step 2: Defining goals/objectives of the program

The goal of the AI-CDSS program is to develop digital health skills and critical thinking of undergraduate medical students toward technologies.

A list of 14 objectives has been established (Table 1) based on a the French medical education program [28], health informatics books [29], scientific articles (e.g.,[30–33]) and team experience [34–39].

2.3. Step 3: Designing an educational strategy

Each session is addressed from the point of view of the AI-CDSS designer and split into three parts:

(1) Theoretical teaching with interactive lectures included short videos, web applications, scientific reports, and quizzes.

(2) Practical teaching with short case studies to solve alone and/or in teams. For example, the theme "Artificial intelligence" was illustrated as follows:

Case study: To propose an AI-CDSS able to automate the reading of antibiograms in developing countries. After brainstorming in a small group, you have to pitch and defend your solution. At the end of the students' pitch, the teacher shows an example of an AI application implemented in real life (video and scientific reports) and engages in

Table 1
Objectives of the AI-CDSS program (AI: Artificial intelligence; CDSS: Clinical Decision Support System).

Understand the basics of the clinical decision process
Understand the basics of AI
Explain the difference between knowledge and data
Understand the principles of AI-CDSS
Discover the history of AI-CDSS
Identify the types of AI-CDSS (e.g., in terms of architecture, and/or objectives (diagnosis, treatment, etc.))
Describe the architecture of AI-CDSS (knowledge-based versus machine learning)
Understand the factors of AI-CDSS adoption, including usability factors
Explain the benefices, issues and challenges related to AI-CDSS
Understand the unexpected consequences of AI-CDSS
Identify the safety issues
Understand the regulatory aspects, including certification and evaluation processes
Identify and discuss the ethical issues
Understand the good practices for AI-CDSS use

discussion with the students.

(3) Brainstorming in small groups on a predefined project that is part of the student examination assessment. The project consists of designing an AI-CDSS for solving a medical issue (e.g., COVID-19 triage [40]). Students play the role of AI-CDSS designers and interact with clinicians who play the role of future users of the AI-CDSS system and provide their expectations for clinical practice. The teacher and clinicians then assign personalized objectives to be achieved for the next session, making it possible for each group to progress continuously in their projects.

2.4. Step 4: Developing an assessment

As explained in Step 3, students are assessed with a project that is brainstormed at each session. The project aims to design an AI-CDSS prototype able to solve a medical issue with two different topics:

- A conceptual topic where computer skills are not needed. Here, the goal is to design an innovative and futuristic AI-CDSS by considering several elements, e.g., the technologies that the AI-CDSS relies on, the modeling of the user interfaces, the integration in the care workflow, the evaluation protocol, and the ethical, regulatory and/or economic issues.
- A technical topic where computer skills are needed. Here, the goal is to implement an AI-CDSS application based on guidelines and/or data that are provided as materials. If the resulting application is judged as high quality, then students have the possibility of writing a scientific article for the conference of Medical Informatics Europe (MIE) referenced in Medline indexation on a voluntary basis.

2.5. Step 5: Implementation into the medical curriculum

The AI-CDSS program is part of "elective courses" and therefore needs to follow the rules for electives at Université Paris Cité medical school, i.e., a limited number of students and split into 5 sessions of 3 h each.

While digital health courses are usually implemented earlier in the medical curriculum [13], we opted here for the middle-undergraduate curriculum, as prior medical knowledge is required for digital health critical thinking.

Likewise, while most digital health courses are usually blended education [13], we opted for in-person learning to foster interactions and fruitful brainstorming on projects, with the possibility of turning to virtual if needed.

2.6. Step 6: Student evaluation and feedback

After the program completion, feedback and opinion were collected with an anonymous electronic form, including questions on the following:

- Demographics
- Content (clarity, quality, new concepts, utility, confidence, free comment)
- Format (educational support, interactivity, enjoyment, free comment)
- Examination (appropriateness, workload, teacher supervision, enjoyment, free comment)
- Global experience (gradation, recommendation) and 3 open comments (interest in the program, positive points, negative points).
- Interest regarding medical informatics (do they wish to continue the program, be involved in AI-CDSS projects, or do an internship in a medical informatics department).

All questions were rated with a five-point Likert scale, except the one on doing an internship in digital health.

3. Results

3.1. The AI-CDSS program

3.1.1. Program

The program is named "Artificial intelligence for Clinical Decision Support System" and is implemented as a stand-alone and elective course at Université Paris Cité medical school (Table 2). It is opened to a maximum of 20 medical students in the fourth years and is organized into 5 sessions of 3 h each, as follows:

- Session 1: AI-CDSS architecture
- Session 2: AI-CDSS for diagnosis
- Session 3: AI-CDSS for therapeutics (drug prescription and dispensation)
- Session 4: AI-CDSS for therapeutics (drug selection)
- Session 5: Usability and Adoption, Advantages/Limits, Certification/ Evaluation and Safety

In each session, clinical, technical, safety, regulatory, and ethical issues are addressed from the point of view of the AI-CDSS designer (Appendix 1). The sessions are split into two parts:

- (1 h 30 to 2 h) dedicated to theoretical and practical teaching (lectures, case studies, etc.)
- (1 h to 1 h30) dedicated to project brainstorming in small groups under the supervision of the medical informatics teacher and/or clinicians.

3.1.2. Student assessment

Students are assessed with a project that consists of designing an AI-CDSS for solving a medical issue. At each session, students brainstormed

Table 2
Features of the AI-CDSS program.

Name	• Artificial Intelligence for Clinical Decision Support System
Implementation into the medical curriculum	• Stand-alone • Elective • Coordinated by the medical informatics team (RT)
Target	• Fourth year medical students
Guidelines used for building the objectives	• French medical education program • Health informatics books, published articles • Experience of the medical informatics team
Educators	• 1 medical informatics teacher • Several clinicians (chosen according to project theme)
Educational approach	• Putting students in the role of AI-CDSS designers • Developing digital health critical thinking and skills
Content	• AI-CDSS: history, architecture, clinical, technical, safety, regulatory, and ethical issues
Organization	• 15 hours divided in 5 sessions of 3 h: o (1h 30 to 2 h) Theoretical and practical teaching o (1 h to 1h 30) Project brainstorming
Modalities	• In person • Computing rooms (1 computer per student)
Educational tools	• Short videos • Web-applications • Scientific reports • Interactive platforms: Moodle, Wooclap
Assessment	• Projects to conduct in small groups that consist of playing the role of AI-CDSS designers and designing an AI-CDSS able to solve a medical issue • Writing a report • Pitch (15 min) to a board composed of medical informatics experts and clinicians

their project under the supervision of the medical informatics teacher and/or clinicians. At the end of the program, each group wrote a report and had to pitch and defend their solution to a multidisciplinary examination board composed of medical informatics experts and physicians involved in health care.

In the academic year 2021–2022 academic year, the theme was "designing an AI-CDSS for emergency phone call triage in pediatrics" because of a broad research project with the SAMU of Paris (a large emergency call center in France) (Appendix 2). Two groups of students chose the "conceptual topic", while two others chose the "technical topic". The examination board was composed of two medical informatics teachers, including the head of the medical informatics department (AB), and three clinicians from SAMU of Paris, including the coleader of the emergency phone call triage structure in Necker's hospital (BV).

3.2. Evaluation of the AI-CDSS program by medical students

In the 2021-2022 academic year, fifteen fourth-year medical students were enrolled in the program, and all answered the evaluation form. They were 21.5 years old on average, and 60 % were women. Sixty-seven percent attended 5 sessions, and 33 % attended 4 sessions out of 5.

For session content, 80 % of students said they learned many new concepts, 74 % said they acquired new skills useful for clinical practice, and 66 % felt more confident in the use and comprehension of technologies for clinical practice (Fig. 1).

Regarding the session format, 100 % of students found the sessions interactive, and 66 % enjoyed taking classes (27 % were neutral). They appreciated the sequence of sessions but also the interactivity and the dynamism of sessions.

For the examination, 100 % of students enjoyed working on the project. They appreciated the project supervision because it helped them to be sure to go in the right direction. They found that the project design induced an extra workload, but it was compensated by a high level of satisfaction with participating in a concrete research project and having the opportunity to solve medical issues (Table 3 – Comments 10&11&12).

For global experience, 80 % of students would recommend the AI-CDSS program to their colleagues. The mean rating was 4.4 out of 5. Some students explained that they better understood the issues related to AI and CDSS in medicine afterward. Others added that they felt more critical regarding technologies but also more confident in AI-CDSS use (Table 3 – Comments 2&3). However, some students complained about difficulty with overbooked agendas, especially as the AI-CDSS program was considered of lower priority than other clinical courses.

Finally, 53 % of students would like to continue to increase their knowledge in digital health; 47 % would be interested in doing an internship in the medical informatics department; and 60 % would like to be involved in research projects on AI-CDSS.

3.3. Strong engagement of undergraduate medical students

The AI-CDSS program stimulated great enthusiasm among the medical students. They truly got involved in the projects and proposed great ideas for AI-CDSS solutions, as highlighted by the examination board in the 2021-2022 academic year.

Moreover, several students sent us requests that reflected their strong interest in (Table 4):

- Writing a scientific article during extra time for the MIE Conference.
- Being involved in a research project on AI-CDSS during their medical curriculum.
- Doing an internship in the medical informatics department.
- Being enrolled in a PhD program, with AI-CDSS as the topic.

From 2021 to 2022, two groups of 4 medical students developed two AI-CDSSs for pediatric emergency phone call triage in pediatrics and assessed their applications with clinicians. Then, they worked during the Christmas holidays to write an article for the MIE conference under the supervision of the medical informatics teacher (RT). They submitted their articles, and both were accepted in March with the mentions "award quality" and "strongly accepted", respectively. The students presented their work in May 2022 at the MIE conference. Four of them asked to continue to work on the project, two will start an internship in the medical informatics department, and one will apply to a PhD program.

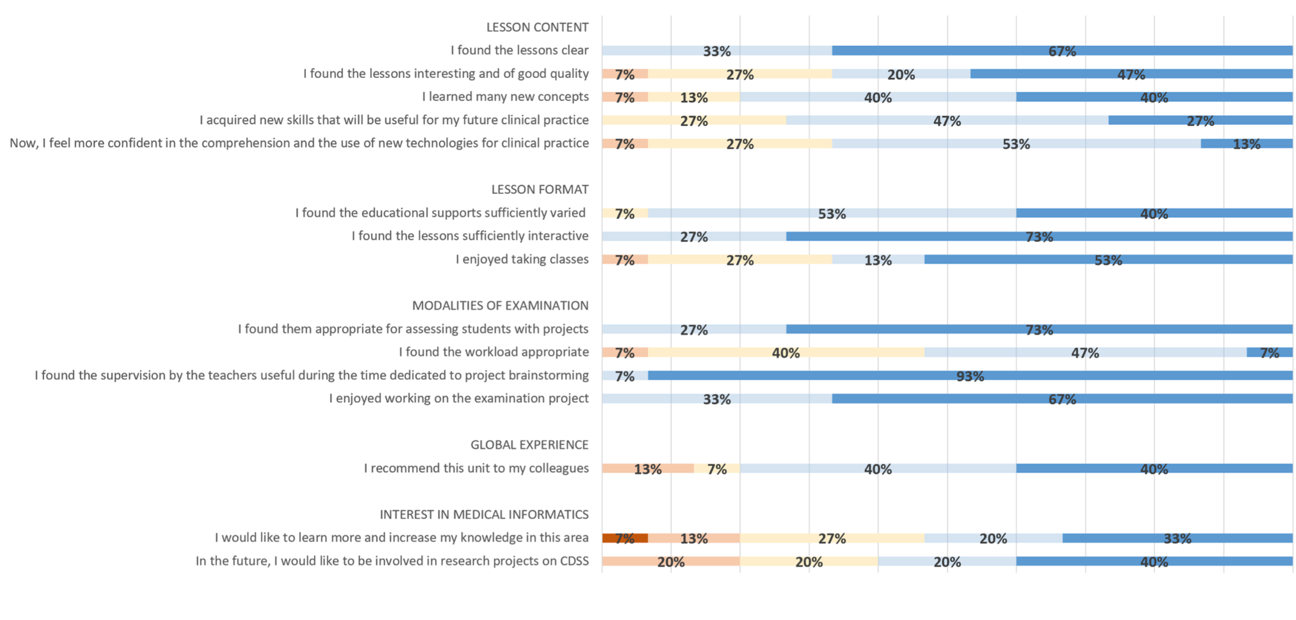

Fig. 1. Students' opinions and feedback (n = 15 students).

Table 3
Example of feedback from students (SAMU: Service d'Aide Médicale Urgente (emergency call center in France)).

Session content	
Interesting and good quality content	*[Comment 1] "Very good sessions and interesting topics. It allows to have a future vision of medicine, and to anticipate the future."*
Useful for clinical practice	*[Comment 2] "This program allows me to discover AI-CDSS and their major role in clinical practice. It is a real topic. Good knowledge of AI-CDSS can truly facilitate our clinical practice."*
	[Comment 3] "A better comprehension of AI-CDSS allows me to take a critical look at the advantages and risks of AI-CDSS and other software in hospital."
Session format	
The format "from theorical to practice"	*[Comment 4] "I truly enjoyed the time allocated for lectures and projects. It allows me to work on the project during sessions but also between sessions."*
In-person or remote teaching	*[Comment 5] "In-person learning is required for comprehension, for asking questions (…) and for project follow up."*
	[Comment 6]: "Remote teaching would be better (university is too far from some of the hospital internships)."
Timing issues	*[Comment 7] "The content is very interesting for beginners in artificial intelligence, like us. Very good approach. However (…) it takes so much time in our busy planning…. However, as it is new and interesting, it compensates……."*
Examination	
Real and engaging project	*[Comment 8] "The project allows me to put theoretical concepts into practice, and thus it makes the learning more fun and concrete."*
	[Comment 9] "The project is more fun and motivating than an exam."
	[Comment 10] "Our projects will be useful for the medical team of SAMU: this adds value to our work, and increases our motivation."
Utility of supervision by teachers	*[Comment 11] "Inviting clinicians from SAMU who were involved in our project was great: it allowed us to be in real life and to understand the expectations of health professionals."*
Global experience and interest in the medical informatics area	*[Comment 12] "I appreciated the approach: it allowed me to discover a new area of medicine that I didn't know."*
	[Comment 13] "I was pleasantly surprised. I truly enjoyed the format of the sessions."
	[Comment 14] "Thanks for giving us the opportunity to discover and enjoy computer science, and more specifically AI-CDSS."
	[Comment 15] "Thank you so much. I knew that I liked the area of artificial intelligence and AI-CDSS, but now thanks to this program: I am convinced of it!"

Table 4
Students' engagement. Summary of students' requests/actions after program completion.

Students' requests	Number of students	Actions
Writing a scientific report with Medline indexation for the Medical Informatics Europe Conference (MIE)	4	Article published (with the 4 students as co-first authors) Title: An interactive interface for displaying recommendations on emergency phone triage in pediatrics [41]
	4	Article published (with the 4 students as co-first authors) Title: Toward a Clinical Decision Support System for helping medical students in emergency call centers [42]
Communication of their work through social networks	4	Students' posts on Linkedin and Instagram
Being involved in a research project on AI-CDSS	4	Involvement in the Ped-IA project, a research project for designing an AI-CDSS for emergency phone call triage in pediatrics
Doing an internship in the medical informatics department of the hospital	2	Internship in digital health planned in summer 2022, with the agreement of the University
Being enrolled in a PhD program	1	PhD planned during future residency

4. Discussion

We implemented an AI-CDSS program in the medical curriculum with the objective of developing the digital health critical thinking of undergraduate medical students. The innovative approach supporting this program puts medical students in AI-CDSS designers' shoes. In the 2021–2022 academic year, fifteen fourth-year medical students were enrolled in the program, and the course was evaluated through a questionnaire sent to all students. The results of the evaluation were excellent and highlighted the strong motivation and interest of the students in this program.

4.1. Strengths and limitations

Strengths. The students' academic level and their high motivation led to results far beyond our initial expectations. At the end of the 15-hour program, the students were able to design a prototype of AI-CDSS to solve a medical issue. This was made possible thanks to the sessions that included brainstorming on projects with physicians but also lessons that were addressed from the perspective of AI-CDSS designers with a large scope (including clinical, technical, safety, regulatory, and ethical issues). The high level of skills acquired by students was highlighted by their significant results: 8 students designed and assessed an AI-CDSS prototype for phone call triage in pediatrics and then wrote two scientific articles that were presented at the MIE conference. Additionally, 74 % of students declared that they acquired new skills useful for clinical practice, and 66 % felt more confident with AI technologies for their clinical practice. They rated the program with 4.4 out of 5, and 80 % recommended the program. This great enthusiasm was highlighted by their strong engagement in digital health: 4 were involved in a CDSS research project, 2 asked to do a hospital internship in the medical informatics department, and 1 asked to conduct PhD training.

Limits. This course is elective and calibrated for a small number of students. Extension to a larger group is difficult due to the high interaction between teachers and students. Based on our experience, we believe that the capacity could be extended to a maximum of 50 students. Moreover, we opted for in-person courses, while blended education is often proposed for digital health [13]. New education tools [43] or online modules such as the American Medical Informatics Association's (AMIA) 10x10 program [44] could be helpful to complement in-person courses. Finally, our program requires teachers with skills in both clinical medicine and medical informatics to select clinically relevant and computationally feasible targets for AI-CDSS [45], and these profiles may still be rare within medical schools. Regarding program evaluation, although all students completed the electronic form, it corresponded to only 15 students. The questionnaire focused on opinions about the content, format, examination, and global experience and interests. A more extensive evaluation should be planned in the future to assess the impact of such programs on both medical skills and critical thinking of medical students toward technologies [13].

4.2. Challenges to the implementation of digital health training in the medical curriculum

Which educational strategy? Traditional educational strategies usually aims to improve students' knowledge of current technologies for specific situations [18,19], with various formats ranging from fictive scenarios

[18,46] to simulations [20,21]. However, these technologies may become rapidly out to date due to their very short life cycle [25]; therefore, educational strategies should also consider the dynamics of digital health and prepare future doctors for next-generation (and still unknown) technologies [8,25,47]. Here, we propose to develop the critical thinking of students from the perspective of medical informatics and artificial intelligence. This should enable students to become active users, increase their capacity to discern the downside of technologies, and stimulate lifelong learning. Approaches close to ours have been published, e.g., the University of California and Los Angeles provided a program including a clinical informatics project but is calibrated for residents [48]; and in Germany, mini-hackathons were conducted [24]. Furthermore, our approach should also develop a mindset of innovation and curiosity so that students can anticipate the future and become partners in digital health projects. A recent survey in 39 countries [12] showed the willingness of medical students to take an active role in the digital health transformation. This has been confirmed by the unexpectedly strong engagement of our students. We hope that this course program will create new vocations in medical informatics.

Which themes? Digital health is a broad medical area that includes various topics [13,14,47,49,50]. A recent scoping review [13] showed that the most-taught themes were medical informatics, computer/information literacy, EHR and telemedicine. Here, we focused on “AI and CDSS” because (i) AI is an emerging topic that has the potential to significantly transform health care, as stated by the FDA [51,52]; (i) AI-CDSS is a meaningful clinical topic; and (ii) AI-CDSS allows us to cover other themes (e.g., EHR) and demystify some abstract concepts (e.g., “interoperability”). Moreover, we believe that the development of AI-CDSS skills during the curriculum could decrease physicians’ fear of technologies [53,54] and encourage AI-CDSS adoption [55,56]. This is critical for maximizing the efficacy of AI-CDSS in the future [47,54]. Likewise, this should enable them to be active in the development of responsible AI-CDSS that incorporate ethics, explainability, and integration into the clinical workflow.

Which format? Digital health courses are usually integrated into existing clinical programs [13]. We believe that stand-alone courses are required for providing an overview of digital health to medical students but also for highlighting the need to develop such skills for future doctors. Until now, most medical schools around the world have considered digital health as “secondary” and have not yet implemented courses on this topic [14,13,57,58]. This attitude could increase the gap between the rapid advancement of technologies and their adoption in routine care [49,58]. In contrast, the American Medical Informatics Association highlights the need for such programs by providing an updated list of stand-alone academic and training programs available in the U.S. [10]. Stand-alone courses should be taught by an interdisciplinary team [59,60]. Here, we invited clinicians to participate in brainstorming, which enabled them to obtain new insights regarding the role of medical informatics in health care. Thus, we assume that stand-alone courses provided by an interdisciplinary team are also an opportunity to involve senior clinicians in the digital transformation.

Which target? Although most digital health programs target first-to-third-year medical students [13], we targeted fourth-year medical students who have already discovered clinical routines in hospital wards. Ideally, digital health programs should be progressive and ubiquitous in medical curricula [47,60]. It should be implemented for undergraduate, postgraduate and medical doctors in continuing professional development [45]. In the U.S., the University of California Los Angeles developed a clinical informatics program for physician trainees [48], the Harvard School of Medicine offered elective rotation for residents in the field of clinical informatics [48], and the University of North Carolina proposed a residency training track for clinical informatics in psychiatry [60]. Likewise, digital health programs should also be implemented for other health care professionals, such as nurses [61,62]; e.g., in the U.S., Adelphi University [63] implemented a “smart home lab” for nurse health informatics training.

5. Conclusion

We implemented an AI-CDSS program for undergraduate medical students based on an innovative approach that consists of putting students in AI-CDSS designers’ shoes. This educational strategy generated great enthusiasm from both students and senior clinicians involved in the program. Such initiatives are crucial for developing digital health skills and critical thinking of medical students toward AI technologies. We expect that such programs could help future doctors work in fast-evolving digitalized environments and position themselves as key leaders in digital health.

Author contributions

Program design, implementation and evaluation: RT.
Program involvement: RT, AB, BV, FC.
Educational board: CC, CL, PR.
Writing, reviewing and approvement: RT, NPS, CC, FC, CL, PR, BV, AB.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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SUMMARY TABLE

What was already known on this topic?

- Digital health programs are urgently needed to accelerate the adoption of Artificial Intelligence and Clinical Decision Support Systems in clinical settings.
- Such programs are still lacking for undergraduate medical students, and new approaches are required to prepare them for the arrival of new and unknown technologies.

What this study added to our knowledge?

- Putting students in AI-CDSS designers' shoes seemed to be a fruitful and innovative strategy to develop digital health skills and critical thinking toward AI technologies.
- This educational strategy generated great enthusiasm from both students and senior clinicians involved in the program.
- Such programs could help future doctors work in fast-evolving digitalized environments and position themselves as key leaders in digital health.

Appendix A:. Organization of the AI-CDSS program for the 2021–22 year academic (AI-CDSS: Artificial Intelligence-Clinical Decision Support System)

SESSION 1: ARTIFICIAL INTELLIGENCE FOR AI-CDSS

Artificial intelligence:

- Definition, History

AI-CDSS:

- Definition
- Examples of historical and recent AI-CDSS (e.g., MYCIN, Watson)
- Architecture of Knowledge-Based AI-CDSS
  - *Case study: Designing a knowledge-based AI-CDSS for child pneumonia*
  - *Case study: Comparing several decision support systems for COVID-19*
- Architecture of Machine learning AI-CDSS
  - *Case study: the French national health data warehouse ("Système National des Données de Santé")*
  - *Case study: Designing an AI-based mobile application to fight antibiotic resistance*

Brainstorming time on project

SESSION 2 – PART 1: DIAGNOSTIC AI-CDSS

Human decision diagnosis

- Medical errors and impact
- Diagnosis reasoning

Diagnosis AI-CDSS

- Type, Architecture
- Knowledge-Based AI-CDSS
  - *Case study: Dombal et al., Internist, QMR, DxPlain, Scoring systems*
  - *Case study: Test, review and critical analysis of diagnosis DSS, dedicated to patients or physicians*
- Machine learning AI-CDSS
  - *Case study: radiomics for breast cancer diagnosis*
  - *Case study: review of scientific reports (e.g., Gulshan et al [64] about IdX-DR for retinopathy diabetic)*

Ethical issue

- Can AI substitute physicians?
  - *Case study: Application to AI for skin lesion detection*

Brainstorming time on project

SESSION 3: THERAPEUTIC DECISION SUPPORT SYSTEM

Drug prescription

- Medical errors and impact
- Medication circuit
- The five rights of medication administration

AI-CDSS for drug checking

- Type, Architecture
  - *Case study: Comparison of several types of prescription AI-CDSS*
  - *Case study: Comparison of the content of several drug databases*
  - *Case study: Generation of alerts from the drug database "Theriaque"*

AI-CDSS for drug dispensation

- Type, Architecture
  - *Case study: e-prescription*
  - *Case study: barcodes*
  - *Case study: automated insulin delivery system for diabetes management*

Safety issue

- Unintended consequences of AI-CDSS

Brainstorming time on project

SESSION 4: THERAPEUTIC DECISION SUPPORT SYSTEM

AI-CDSS for drug selection

- Type, Architecture
- Paradigm of Evidence-Based Medicine (Clinical Practice Guidelines (CPG), formalization)
- Paradigm of Personalization Medicine (-Omics data, personalized therapy)
  - *Case study: Formalization of CPG and comparison with algorithms developed by national authorities*

Safety issue

- AI-CDSS malfunctions and consequences

(*continued on next page*)

(*continued*)

Brainstorming time on project
SESSION 5: USABILITY AND ADOPTION, ADVANTAGES/LIMITS, CERTIFICATION, EVALUATION AND SAFETY OF AI-CDSS **Usability and Adoption** - Factors of AI-CDSS adoption - User-centered design approach - Usability principles and design techniques ■ *Case study: Review and critical analysis of various user interfaces, and their impact on AI-CDSS users* **Advantages, Limits and Unintended consequences Regulatory issue - Certification and Evaluation** - AI marketing authorization by drug agency (France, Europe, FDA) - Evaluation of AI applications as medical device for reimbursement ■ *Case study: "Algorithms Decision Systems indexed by drug" in certified French AI-CDSS for prescription* **Safety issue** - Data protection - Cyberattack ■ *Case study: Safety of medical applications available on the "Health Apps Library Portal" from NHS* **Brainstorming time on project**

Appendix B:. Examination projects for the 2021–22 academic year

Project has to be conducted in team composed of a maximum 4 members.

Examination project - Topic 1This project does not require any computer skills.

Objective:
To propose an innovative and futuristic AI-CDSS for emergency phone triage in pediatrics.

Methods:
1) Understanding the context, needs and issues of emergency phone call triage in pediatrics
2) Designing an AI-CDSS able to solve the medical issue:
   o Clarifying the objective of the AI-CDSS
   o Brainstorming on the most appropriate architecture
   o Keeping in mind the care workflow
   o Designing the AI-CDSS interface
3) Designing a protocol for assessing the AI-CDSS

Report:
The report should include:
- Succinct description of the medical issue
- Objective of the AI-CDSS
- Description of the AI-CDSS (type, architecture, data/knowledge, etc.)
- Design of the AI-CDSS interface
- Integration of the AI-CDSS in the care workflow
- Design of an evaluation protocol for the AI-CDSS
- Ethical, regulatory and economic issues
- Conclusion
- Contributions of each student

Examination project – Topic 2
This project required computer skills.

Objective:
To design, implement and evaluate an application for emergency phone triage in pediatrics.

Methods:
1) Conducting a literature review of AI-CDSS developed for emergency phone triage using Pubmed and Google. Be careful with the usability of the user interface of these systems
2) Analyzing the textual recommendations produced by the medical team of SAMU, and identifying the generic reasoning to implement in your application
3) Implementing the application using the textual recommendations. Please feel free to choose any programming language
4) Evaluating the application by medical users

Report:
The report should include:
- Computer code and the link for testing the application
- Presentation of the application
- Results of the evaluation
- Contributions of each student

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