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On-Line Project-Based Learning on Healthcare Technologies Against Epidemic Diseases: A COVID-19 Case Study*

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Quality technical education on healthcare technologies is still inaccessible to young adults in low-resource settings due to high costs, low-tech environments, and gaps in learning materials. The online and open-source collaborative Project-Based Learning (PBL) methodology intends to introduce early-career engineers into the development of healthcare technologies by allowing students from all around the world, regardless of background or place of origin, to engage in collaborative design methods, the use of open-source resources and learning experiences from experts in the field. This paper discusses a case study in which the aforementioned methodology was implemented, the "COVID-19 Innovation Competition and Design Bootcamp 2020", which brought together 105 participants from 22 countries, mostly in Africa, to conceptualize the design of 10 medical devices in two weeks for an integral management of the COVID-19 pandemic that is applicable to other infectious disease outbreaks. The presented experience demonstrates that highly formative virtual PBL experiences can be carried out, in a cost-effective way and in connection with real societal needs, for which remarkable solutions can be found, by virtue of multidisciplinary and international cooperation. Our findings demonstrate that even if it is difficult to reach the degree of project completion achievable with longer-term and on-site design-build experiences, on-line PBL has been shown to promote students' professional skills in an effective way.

Keywords: Project-based learning; collaborative design; COVID-19; CDIO; medical device

1. Introduction

In order to solve the world's greatest challenges through science and technology, engineering education should be inclusive and not leave anyone behind. At present, engineering education faces the challenges of accessibility and inclusiveness, especially considering that engineering studies tend to be expensive, within higher education, due to the amount of practical activities and supporting materials needed. [1].

Project-based learning (PBL) methodologies, which are widely considered as holistic approaches to engineering education, also require varied

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resources and equipment, which are not always accessible in remote regions or in low- and middle-income settings. In consequence, the desired equitable access to high-quality engineering education is a challenging objective, included in the Sustainable Development Goals (SDGs) [2, 3]. Moreover, sanitary emergency situations as those created by the most novel SARS-CoV-2 outbreak and the derived COVID-19 pandemic may lead to a lockdown of higher education institutions and increase education inequalities, due to technological breaches [3].

During the last two decades, open online learning resources, YouTube tutorials, webinars and other initiatives for sharing knowledge, including Wikipedia as a pioneering example, have reformulated the way people access information, receive training and gain knowledge [1]. Massive open online courses (MOOCs), which are open-access online courses that allow for unlimited participation [4], have opened universities and their courses to students worldwide, although in many cases the payment of fees is still required for certification, which limits their potential impact for fostering the democratization of higher education worldwide [5, 6].

Online competitions and hackathons (i.e. competitive design events involving multidisciplinary collaboration during a concise and intense period of time [7]), for developing technological solutions for communicable diseases, have also been carried out in the past few months, in some cases counting with thousands of participants and reaching dozens of ideas and technological concepts [8].

However, a common problem with MOOCs, virtual hackathons and other online learning activities is their usually very low completion rates, which minimizes their transformative potential. The typical absence of lessons and supporting contents in online hackathons, which are conceived as express competitions with scattered mentoring, and the very limited face-to-face interaction in MOOCs, which mainly rely on asynchronous recorded lessons, may lead to a lack of students' engagement [9, 10].

More recently, on-line (or virtual) PBL has also been proposed as a methodology for alleviating the impact of the mentioned lockdown on engineering education; also as a way for keeping students motivated, in spite of being forced to receive online lectures, with the consequent lack of interaction with their peers [11].

PBL provides students with the opportunity of learning by doing, students solve authentic problems with interdisciplinary knowledge, skills, and confidence beliefs [12–14]. Thus, activities involved in a PBL are typically learner-centered, real-based, and monitored by a teacher who acts as a facilitator, not as an instructor [15]. This methodology has been successfully translated in a virtual environment thanks to the use of information and communication technology tools, including dedicated online learning management systems, such as Edmodo™ or BlackBoard™ [16, 17].

Furthermore, these tools enable collaborative learning, so students can develop their projects, communicating and collaborating, synchronously and asynchronously, with teammates and their professors and mentors.

Although there is a limited number of studies comparing on-site and on-line PBL, these indicate that if online activities are properly implemented, they can be more effective or equally effective as in-presence teaching/learning activities [12, 18, 19].

However, some issues have been highlighted, such as surrogate interactions within participants and the related difficulty to recreate the group dynamics in the virtual environments, which may lead to a decrease in the motivation of students over time [13].

Authors argue that successful, engaging, affordable and highly transformative international PBL experiences can be performed, counting just with the support of widespread telecommunication tools, with the help of open source software, and with the aid of online information repositories.

We applied these concepts to the biomedical engineering (BME) field, which stands out for the need for multidisciplinary teams capable of systematically addressing the development of medical devices considering clinical, social, economical, technical, safety and regulatory issues.

As suggested by the Kahawa Declaration, "*training the new generation of biomedical engineers in teamwork and communication skills and making them aware of the social impact of engineering decisions by means of PBL strategies [...] can be a basic aspect of the global strategy towards improved biodevices addressing global health challenges*" [20].

The present paper summarizes the "COVID-19 Innovation Competition and Design Bootcamp 2020" experience, performed on a complimentary basis in June 2020 with 105 participants from 22 countries (21 in Africa and 1 in Asia, Fig. 1), who completed the engineering design of 10 medical devices in two weeks of intense dedication.

This was achieved thanks to keynote speeches, frontal classes and webinars, during which participants interacted with the speakers, as well as teamwork sessions, where they had the opportunity to discuss in groups with their mentors and co-design their projects.

Inspired by the principles of the Kahawa Declaration [20], the Bootcamp was carried out on a free basis, using open source software resources and with the support of the UBORA platform, a universal repository for medical technology projects, focused on promoting the accessibility of healthcare technologies through open source medical devices [21–23].

The following sections describe the learning objectives, teaching-learning methodology and employed resources, before detailing the main achieved results and discussing the benefits, potentials, and challenges of these types of experiences.

2. Methodology

2.1 The General Framework of the On-line PBL Experience

The "COVID-19 Innovation Competition and Design Bootcamp 2020" was designed to run online over two weeks (10 days, from Monday 15th to Friday 19th, and from Monday 22nd to Friday 26th June). The program was organized to allow 105 participants, supported by technical and business mentors (from Africa, Europe, Asia, and North America), to go through the design of a technology solution for overcoming the issues that have and continue to arise from the COVID-19 pandemic.

The Bootcamp was built on ongoing initiatives by the United Nations Economic Commission for Africa (UNECA), the United Nations Educational, Scientific and Cultural Organisation (UNESCO), the African Union Commission (AUC), supported by the Dpt. of Science and Innovation of South Africa, to boost the capacity of member States to harness and effectively utilize science and technology for development and increased resilience [24]. Considering that several youths had demonstrated their potential to contribute and offer innovative solutions to meet some of the shortages of medical supplies needed to fight COVID-19, the Bootcamp was implemented for harnessing their creativity, entrepreneurial aspirations, risk-taking attitudes, teamwork, innovation drive, and sustainability awareness, which are necessary to help build robust national innovation ecosystems that will sustain and drive Africa's development into the future.

2.2 Technical Management of the Bootcamp Experience

The call for participants and mentors was published on the websites of UNECA, and circulated among the UNECA and UNESCO stakeholders, the UBORA community, the African Biomedical Engineering Consortium (ABEC [25]), the International Federation for Medical and Biological Engineering (IFMBE [26]), and Engineering for Change (E4C, [27]). By the end of May 2020, more than 260 requests were received in two weeks from Africa, Europe, and Asia, to participate in the Bootcamp.

From these, 105 participants were selected, based on their CV, motivation letter, and previously developed projects, with an average age of 24 ± 4 years (span 18–30) and 30% female. Most of the participants were enrolled into a university program linked to engineering and technology, but there were several students (10) from medicine and allied sciences.

All the mentors (27), speakers (9), and lecturers (12) (for a total of 41 people, given 7 with the double role of mentor/lecturer) participated with no monetary compensation, given the meritorious and not-for-profit type of event. The Friday before the Bootcamp, in dedicated meetings, mentors were informed about their role and the use of the UBORA platform.

In Fig. 1, a map of all the nationalities involved in the Bootcamp with different roles (participants, mentors, facilitators, speakers) is shown.

The Bootcamp website was the main source of

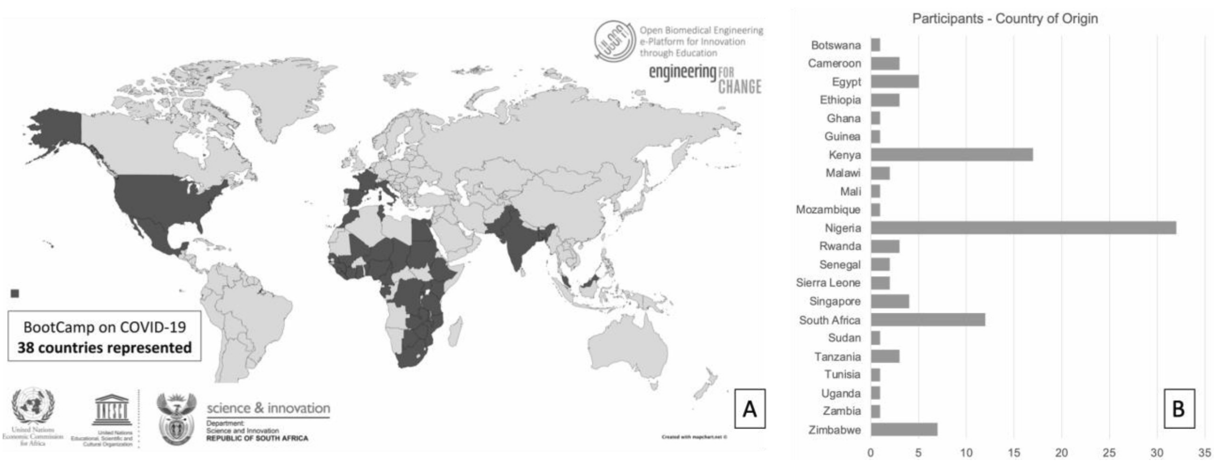

Fig. 1. Map of all 38 nationalities involved in the Bootcamp on COVID-19, including participants, mentors, lectures, and keynote speakers (A); country of origin of the 105 participants (B).

information for participants. In addition, a daily newsletter sent by email informed participants about the forthcoming programs, including the assignments. At the group level, students were invited to create private chats, including their mentors, to facilitate communication. A Facebook group was also created, for promoting the informal spirit of an on-site Bootcamp, and to let people interact in a more familiar way.

Zoom was used as the main communication platform and the UBORA platform was used as the key online co-creation environment for fostering creativity, sharing documentation, and guiding the engineering of open-source medical devices (OSMDs). All teaching materials (slideshows, papers, videos) were made available on the website for all participants and all the sessions were recorded and uploaded to YouTube [28].

3. Learning Goals and Teaching Strategy

The learning objectives, structure, and teaching-learning methodology proposed for the Bootcamp followed the Conceive-Design-Implement-Operate (CDIO) scheme empowered by the central role assigned to standard, regulations, and clinical needs, thanks to the UBORA platform [29–31].

This CDIO-UBORA biomedical engineering education model is a highly structured, formative and intense PBL initiative, with students focusing on OSMDs and living through the medical need identification, product specification, conceptual layout design, implementation, and operation stages.

Following the CDIO-UBORA model, the programme combined: (1) a basic core of lessons linked to essential aspects for successfully engineering medical devices in connection with open source software and hardware movements; (2) specialized keynotes speeches on COVID-19 focusing on sustainable development and advanced research topics; (3) hands-on activities and meetings between student groups and mentors; and (4) project presentations. The detailed program is available online [32] and schematically presented in Table 1.

The website also contains links to the teaching materials, information about keynote speakers, lecturers, and mentors, and links to additional resources. All the activities were scheduled according to East African Time (EAT, UCT+3), usually from 11:30 AM to 17:30 PM to facilitate the participation of students and mentors across Africa (three time zones), but also the productive involvement of participants from Europe (Italy, Spain) South East Asia (e.g., Singapore) and North America (e.g., the United States).

The general daily program structure foresaw a class on device development in the morning (1 h), a keynote speech immediately before the lunch break (45 mins), and a class early in the afternoon (1 h). Webinars (45 mins) on technical topics were organized at the end of the day. The topics of the classes followed the scheme suggested for the project development (see Fig. 2). The number of lessons decreased along with the Bootcamp, which afforded more space for hands-on activities.

4. Design Activities

The projects to be developed by participants were framed in four tracks, related to COVID-19 and identified after discussion with stakeholders:

(1) enhanced medical devices and personal protection gear design and fabrication;
(2) alternative tools for efficient and effective contact tracing and isolation;
(3) new approaches for testing and diagnosis;
(4) reliable and cost-effective medical devices for therapy.

Participants were divided into ten teams according to their preference on one of the abovementioned tracks (as expressed during the registration) and their skills (evaluated through their CVs). Gender balance and internationalization were also promoted. The teams were communicated before the beginning of the learning experience, and three mentors were assigned per team. With the help of mentors, and guided by the UBORA metastructure, the design process followed the steps illustrated in Fig. 2:

- identification of the device and its specifications/standards (days 1–2);
- design (conceptual design days 3–5, more complex design aspects up to day 9);
- planning sustainability (days 7–8);
- documentation (on the UBORA e-infrastructure, every day).

Being a virtual PBL experience, the typical physical prototyping and testing stages, which usually correspond to the "I" or "implementation" and "O" or "operation" phases of CDIO experiences, were not feasible in just two weeks of time. Consequently, they were replaced by computer-aided designs and simulations, as virtual prototypes, by detailed selections of materials and commercial elements for manufacturing and building the designed medical devices, and by focused studies on devices' economic and environmental sustainability and on supply chain issues. In a way, the final presentations may be seen as the final part of any CDIO cycle in engineering education and the different videos illustrating how the devices may

Table 1. Detailed program of the Bootcamp on COVID-19. Background meanings: Light grey = General session; Grey = keynote. Border meanings: Thick = Class; Dashed = webinar

	Monday 15	Tuesday 16	Wednesday 17	Thursday 18	Friday 19	Monday 22	Tuesday 23	Wednesday 24	Thursday 25	Friday 26
11:00 - 11:30	Institutional greetings	Teamwork with mentors	Teamwork with mentors	Teamwork with mentors	Teamwork with mentors	Teamwork	Teamwork with mentors	Teamwork with mentors	Teamwork with mentors	Teamwork with mentors
11:30 - 12:30	Introduction to the Bootcamp	Creativity promotion - Diaz Lantada, Munoz Gujosa	Standards and regulation - Di Pietro	Teamwork with mentors	Teamwork with mentors	Teamwork with mentors	African market understanding focused on Medical Devices - Murage	Teamwork	Teamwork	Meeting with mentors / teamwork
12:30 - 13:15	What is COVID-19? Outlook on Africa - Karanja	Potential economic and social impact of COVID-19 in Africa - Geanina Montero	Advantage of robotic system in COVID-19 for reducing propagation - Serge	EpiCOVID: A Brief Overview of COVID-19 - Jet Lim Yong Kiat	Teamwork with mentors	Keynote: Environmental Sustainability - Quaye, Akoi	Advanced biomedical tools for modelling biological systems - Ahluwalia	Using deep-learning for detecting COVID 19 - Magliaro	The impact of communicable diseases on rehabilitation systems from developed and developing countries - Khundi	Meeting with mentors / teamwork
15:00 - 16:00	UBORA project management tools - Di Pietro	Project management - Ballesteros ; Rodriguez Rivero	Human Centered Design - Elizabeth Johansen	Project Management - CAE software- Munoz Gujosa	What is AI? - Mendoza Buenrostro	Beyond Winning Ideas - Tang	Standard and innovative supply chain - Diaz Lantada, Rodriguez Rivero	Teamwork	Teamwork	Final project presentation
16:00 - 17:00	Meeting with mentors / teamwork	Meeting with mentors / teamwork	Webinar: Example of design specification - Mikeka	Teamwork with mentors	Intermediate project presentation	Webinar: innovation from the groud - Kebede	Teamwork	Webinar: innovation from the ground - Karene Melloul	Awarding Ceremony UBORA Design Competition	Final project presentation
17:00 - 18:00	Q/A with the Heads of ECA and DDG of UNESCO	Meeting with mentors / teamwork	Meeting with mentors / teamwork	Meeting with mentors / teamwork	Intermediate project presentation	Meeting with mentors / teamwork	Meeting with mentors / teamwork	Meeting with mentors / teamwork	Meeting with mentors / teamwork	Closing session

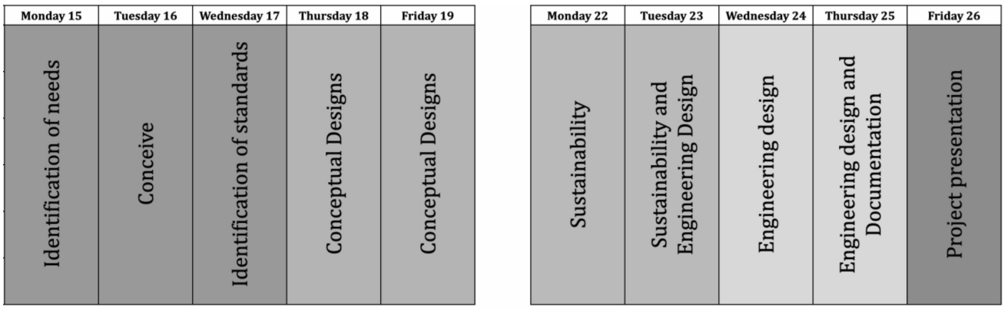

Fig. 2. General scheme of the design activities. By the end of week 1, the designs should be documented on UBORA incorporating work packages 1 & 2. By the end of week 2, the designs should be documented on UBORA including work package 3. A business model canvas was available on UBORA in work package 5, linked to sustainability and global impact promotion strategy.

operate, together with the documentation in UBORA, were considered adequate replacements for the operation phase.

5. Assessment of Projects, Learning Outcomes, and Participants Satisfaction

During the intermediate (Friday 19th) and final presentations (Friday 26th), participants had the opportunity to present and clarify their design process to other students, mentors, and stakeholders (from hospitals, academia, industry, civil society).

The following criteria were considered during the evaluation of the projects by the mentors: technical implementation (10 points), quality of the presentation (10 points), potential impact (10 points), and documentation on UBORA (10 points). Votes were indicated by filling a shared Google spreadsheet, accessible to all mentors. Together with this summative assessment, a formative evaluation was given to each group at the end of their presentation.

The other participants were asked to globally evaluate the projects of the other teams with a scale from 1 to 10 using the poll tool provided by the communication platform.

For taking into account the competition dimension of the Bootcamp, a final ranking was drawn up by averaging the participants' evaluation (properly scaled) with the median evaluation provided by mentors. To avoid any bias in the final ranking, mentors were asked to not express any vote for the team they mentored, while the evaluation of the documentation completeness was provided by the managing team of the UBORA e-platform, part of the organizing committee of the Bootcamp.

Two anonymous and voluntary questionnaires were distributed among participants, at the beginning and at the end of the event, respectively.

The questionnaires, through a series of 5-point Likert-like items, aimed at evaluating learning outcomes and the satisfaction about the organization of the Bootcamp.

In particular, the first questionnaire was designed to understand the "experience in the design of medical devices" (10 items) and the "attitude to teamwork" (10 items) of participants.

The second questionnaire was more articulated, aimed at assessing: (i) the effectiveness of lectures for developing competencies in the design of medical devices (10 items); (ii) the participant perception about the PBL activities (5 items); (iii) the effectiveness of the Bootcamp experience for developing engineering competences (5 items) and attitude to teamwork (6 items). Finally, a section of the second questionnaire was dedicated to feedback about the organization of the Bootcamp, asking about the ICT tools for communicating between teammates and for attending the school, and about the usefulness of the UBORA platform and the support received from mentors.

At the end of the Bootcamp, a questionnaire, similar to the second one administered to participants, was distributed among mentors for assessing: (i) their perception about the effectiveness of lectures for scaffolding competencies in the design of medical devices (10 items); (ii) their perception about PBL activities of participants (5 items); (iii) the effectiveness of the Bootcamp experience for developing their competences in mentoring PBL activities (8 items). Also in this case, a section of the questionnaire was dedicated to feedback about the organization of the Bootcamp.

The questionnaires and detailed answers are available in the supplementary information (SI). Data are expressed as median and interquartile range.

6. Results: Learning and Innovation Outcomes

6.1 Design Activities

A total of 10 projects were developed by teams, and documented on UBORA, according to EU MDR 2017/745 and relevant standards (Table 2 and SI).

Devices cover all the proposed topics, in connection with COVID-19 and other infectious diseases: enhanced prevention systems, improved diagnostic and monitoring systems and innovative therapeutic devices. Even if physical prototyping was not possible, due to temporal (two weeks) and material restrictions (on-line PBL), the variety of solutions proposed, their degree of innovation and their sharing among teams, through the planned public presentations, promoted interesting debates and discussions and helped to maximize global learning. In most cases, a detailed design was reached, which included: ad hoc computer-aided designs of main geometries, optimizations through simulations, selection of commercial materials and components for future implementation, and impact evaluations. All teams documented extensively their advances and prepared two public presentations, one summarizing the concept at the end of the first week and another summarizing the whole experience and design results at the end of the second week, as main outputs for assessment. Individual dedication along the two weeks accounted for around 80-100 hours of personal efforts, including attendance to lessons, keynote speeches and webinars, and teamwork activities, which corresponds to a 3-ECTS course performed as an "express CDIO" experience, as certified for the participants. Table 2 summarises the evaluation of the participants' projects according to the criteria, presenting the median of the votes provided by mentors. None of the projects received a negative evaluation.

To illustrate the degree of completion achieved, Fig. 3 presents the results from Team 1, which developed the "Covid Auxikit", including the conceptual design sketches achieved at the end of the first week (3A), after adequate medical need identification, specification, classification and selection of relevant standards, and the final design results, showing the final CAD models and electronic layout for a system capable of controlling different UV lamps with an incorporated delay for enhanced safety (3B-C).

6.2 Learning Outcomes

An average number of 70 participants per day was monitored, which constitutes a success in terms of engagement, from the perspective of virtual teaching-learning experiences, also considering the young age of many participants. A total of 74 participants successfully completed the two weeks long sessions and received certificates. Following through a long online and intensive learning event requires a relatively high level of intrinsic motivation and self-discipline [4]. Considering for example MOOCs, successful graduates tend to be older (in the range of 25–30 years) and already hold a first degree (80%) [4].

An assessment of the learning outcomes can be drawn by analyzing the questionnaires provided to participants and mentors. A total of 70 and 51 responses were received from participants for the questionnaires before and after the Bootcamp, respectively. A total of 19 responses were received from mentors. Answers are provided in the supplementary information (SI) summarized as median and 1st–3rd interquartile range (IQR), by associating "1" to "strongly disagree" and 5 to "strongly agree".

In the first questionnaire, five-points Likert scale-like questions were asked to understand the participants' "experience in the design of medical devices" and their "attitude to teamwork". Results

Table 2. Evaluation of the projects developed by participants during the Bootcamp on COVID-19. A detailed description of the projects is provided in SI, together with the link to their documentation on the UBORA platform

		Evaluation from mentors (median)						
Team	**Project**	**Technical Implement.**	**Impact**	**Presentation**	**Documentation (on UBORA)**	**Total**	**Evaluation from participants (scaled on a 40-point scale)**	**Average Mentors / Participants**
1	Covid auxikit	7	8	7	7	29	30.6	29.8
2	Standalone Self Regulated Oxygen Delivery System HFNC	7	7	7	7	28	25.0	26.5
3	TraCi	8	8	8	7	31	25.3	28.1
4	Automated Hand Washing / Sanitizing System	7	7	7	7	28	27.8	27.9
5	COVID-19 Rapid TestPro	7	6	7	6	26	29.5	27.7
6	Ventilator Splitter	8	7.5	7	7.5	30	28.5	29.2
7	USAFIBORA hand-wash station	6	6	6	6	24	22.1	23.0
8	GUNDUA-HLANGANISA – COVID-19 diagnosis using assembling method for imagery	6	6	6	6	24	27.8	25.9
9	Shield 9 Scanners	7	7	7	6.5	27.5	29.7	28.6
10	TraceAfrica app	6	7	7	6.5	26.5	26.4	26.4

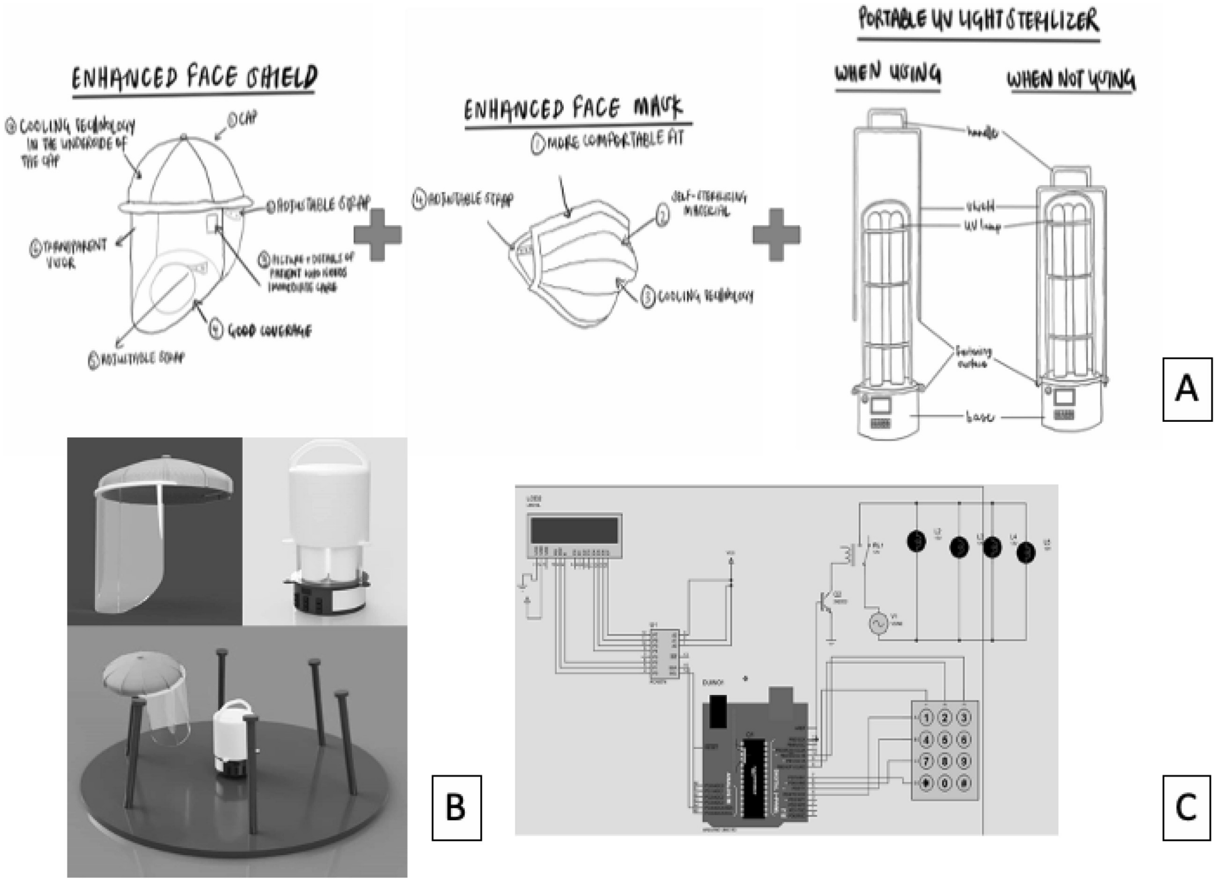

Fig. 3. Conceptual design (A), CAD models (B), and electronic layout (C) from the "Covid Auxikit".

indicate high participants' confidence in their design capabilities (median 4 = "agree", IQR = 1), and a very strong attitude to teamwork (median 5 = "strongly agree", IQR = 1).

Starting from these bases, the large majority of the participants considered the Bootcamp experience as effective for further developing their engineering competencies (median 4, IQR 1). In particular, both frontal classes (lectures, keynotes, seminars) and PBL design activities received appreciations from participants (median 4, IQR 1). Equal indications were provided by mentors: effectiveness of lectures, design activities, and the entire experiences were considered effective for scaffolding the design abilities of students with a median of 4 and IQR 1.

Attitude to teamwork, already high at the beginning of the Bootcamp, was confirmed with similar results in the final questionnaire by participants. Interestingly, mentors considered the Bootcamp experience as effective for increasing their competencies in mentoring PBL activities.

6.3 Feedback on the Bootcamp Organization from Participants and Mentors

Feedback on the general organization of the Bootcamp was asked to all participants and mentors, in a dedicated section of the questionnaire on the learning outcomes.

The communication of the Bootcamp activities (e.g., timetable, assignments) was considered fluent (e.g., positive answers from participants were more than 90%, Fig. 4A). The evening newsletter (sent by email at the end of each day, with the day-after program, including links to the Zoom's room, and to the recorded videos) was the preferred communication channel (Fig. 4B). The sharing of video links proved useful along with the Bootcamp, especially for students who could not join some sessions, due mainly to the cost of the internet connection (e.g., data-based contracts with internet providers) or to university workload, and wished to catch up.

Availability of videos may also support the replication of the experience or the implementation of similar bootcamps or "express CDIO" initiatives connected to OSMDs in the future.

The choice of Zoom as a virtual platform for performing the Bootcamp was successful (Fig. 4C), with half of the participants using their mobile phones for connecting (Fig. 4D). This information is fundamental for future events like this, in case live demos or interacting sessions will be organized.

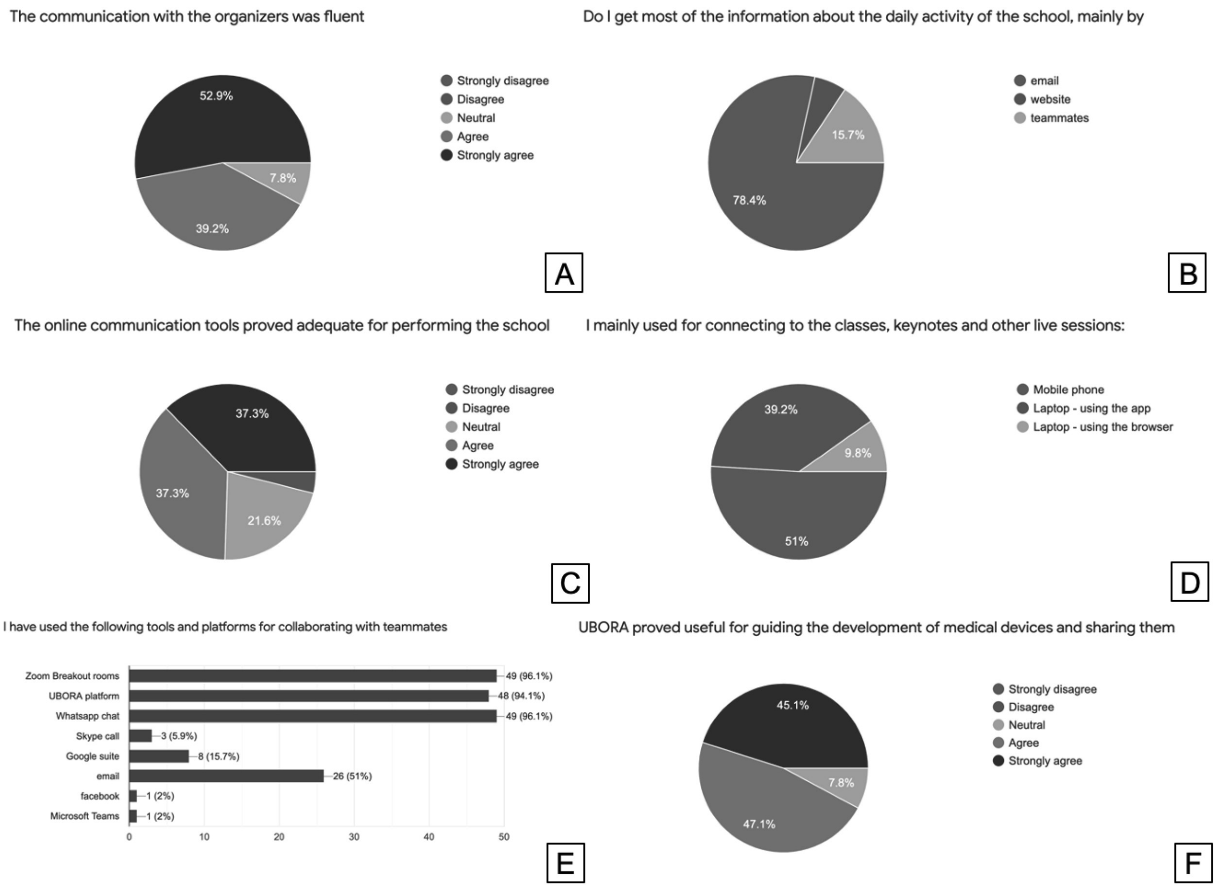

Fig. 4. Feedback from participants on the efficacy of communication (A) and the preferred communication channels with organizers (B). Feedback on the Zoom Platform (C) and how the participants attended the various sessions (D). Feedback on the communication tools used by participants for the development of their project (E) and on the UBORA platform (F).

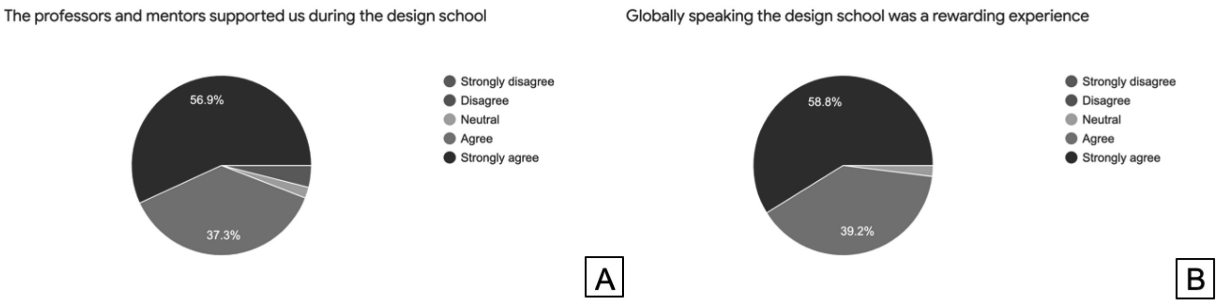

Fig. 5. feedback from participants on mentors (A) and the Bootcamp as a whole (B).

The tools suggested for carrying out the project (Zoom breakout rooms, UBORA platforms, WhatsApp Chats) were used by participants, which also explored other solutions they were more familiar with (Fig. 4E). UBORA platform was considered useful for designing and documenting the projects by more than 90% of respondents (Fig. 4F). Similar comments and indications were provided by mentors (see SI tables).

Mentors and lectures had a fundamental role in the positive results of the Bootcamp: their commitment was appreciated by participants (Fig. 5A). The negative votes (only 2 over 51) indirectly indicate that the call for mentors and lecturers was effective, and the pre-Bootcamp meetings were important for aligning the teaching/learning strategies.

Generally, the Bootcamp was a rewarding experience for all the participants (Fig. 5B, and SI), as confirmed by the comments left at the end of the questionnaire.

7. Discussion and Lessons Learned

Results from the medical devices designed and the assessment of students' opinions show that the

"COVID-19 Innovation Competition and Design Bootcamp 2020" was a successful on-line PBL experience and it is the intention of the organizers to arrange similar Bootcamps in the near future.

With this experience, the authors demonstrated the feasibility of open online PBL in the field of biomedical engineering and in connection with OSMDs against epidemic diseases, hence somehow also entering the realm of open online service-learning [32].

A virtual PBL can be both successful and rewarding as an on-site experience if properly organized taking into account the specificity of the on-line environment. Mediating the "5C" suggestion proposed by Kaplan and Haenlein [4] for MOOC, the online Bootcamp was organized for promoting the participants' intrinsic motivation:

- Commitment: the participants were involved in small working teams, favoring the interaction and consequently their commitment to attending the Bootcamp. Furthermore, the topic (medical technologies for COVID-19) increased their willingness in participating for identifying solutions for an urgent problem.
- Challenge: according to the original significance, the different background and skills level of participants have represented a challenge in the organization of such Bootcamp, especially in tuning the technical level of analysis of the various subtopics. Nevertheless, this heterogeneity of participants could be considered an advantage in a PBL experience as it brings different perspectives for solving problems.
- Control: apart from the scheduled classes (Table 1), participants have the opportunity to select the most suitable software for their design, as well as communication tools for exchanging information with peers and mentors. At the same time, the UBORA platform helped the participants by providing a structured framework in which maximizing their design efforts.
- Competition: the competition dimension of the Bootcamp helped in engaging the participants; the intermediate check on Friday helped participants to compare themselves with others.
- Contemporaneous: the interactive and in some moments familiar environment created within the Bootcamp increased the motivation of students.

Even if it is difficult to reach the degree of project completion achievable with longer-term and on-site CDIO experiences, which count with physical prototyping facilities [34], virtual PBL has been shown to promote students' professional skills in an effective and efficient way. In this sense, having the structured framework proposed by the UBORA platform allowed participants to fully understand the design process and to collaboratively complete the specific tasks.

Virtual PBL has been demonstrated as a very appropriate teaching-learning strategy for arranging truly international experiences, involving participants from remote regions and low- and middle-income settings, and for affordably promoting high-quality engineering education. This aspect, already pointed out in similar experiences [35], was further confirmed by this Bootcamp. It also proves a very adequate alternative to conventional PBL in special settings and moments, in which educational institutions may not be accessible or may be locked down, as happened during the spring of the year 2020 with the global confinement consequence of the COVID-19 pandemic.

The inequalities of accessing online systems were laid bare, with some presentations failing to flow smoothly due to connection challenges and some participants staggering their connection because their data would not allow continuous connection for two weeks. However, as this was already foreseen for a global environment where about 50% (about 30% in Africa) [36] have no or limited access to an online connection, thus presentations and other learning materials were pre-loaded for download by participants. This allowed all participants to catch up with any material which was not clearly presented online.

Among lessons learned, probably the most relevant advice for successful and rewarding on-line PBL experiences include selecting students based on merit and motivation, and counting with a devoted team of mentors, capable of fostering debate and focused on promoting active learning within teams.

Besides, arranging a relevant corpus of lessons, linked to systematic product development in connection with the field of application, and supporting this basic corpus, with keynote speeches linked to inspiring research topics, are remarkable options for providing content to the PBL experience. Such a scheme, applied here to biomedical engineering and to open source healthcare technologies, can be easily adapted to most engineering fields and systems.

The involvement of a group of experienced international keynote speakers, to present students with the most relevant and inspiring research trends or novelties in the area of interest, complements lecturers from the core sessions in a very synergic way. In this way, even a smartphone turns out to be one of the most powerful learning sustainable instruments [37, 38] available and the relevance of infrastructures for successful higher education fades away.

The motivation of a multidisciplinary team of mentors and their inspirational and learning facilitator roles proves fundamental for actively engaging students and making them perform optimally. Employing co-creation strategies, with students and mentors working together, oriented to real societal demands, and leading to open source solutions for increased impacts, may provide the extra motivation required to overcome the intrinsic limitations of virtual educational experiences, not only in connection with biomedical engineering but also in many other areas of engineering education.

Finally, a lean "on-line PBL experience managing team", for helping the virtual PBL run swiftly and for rapidly taking relevant decisions, proves to be also essential.

8. Conclusion

The presented experience of the "COVID-19 Innovation Competition and Design Bootcamp 2020" demonstrates that highly formative on-line PBL experiences can be carried out, in a cost-effective way and in connection with real societal needs, for which remarkable solutions can be found, thanks to multidisciplinary and international cooperation. Online PBL is challenging to implement and has some drawbacks, but it also brings considerable benefits, as compared with traditional on-site PBL.

Online human interactions are very different from real-life situations and establishing an adequate learning environment is more complex in virtual PBL. Complete CDIO experiences are clearly more difficult to implement, as there are no physical labs available for the participants, although virtual prototyping and virtual labs may, to some extent, compensate for this limitation.

Combining a common virtual environment for the lessons, keynotes, and presentations, with online platforms or repositories oriented to remote project management, and with additional informal communication tools, selected according to students' desires, helps to guide and promote interactions within and between teams.

As for the benefits, online interactions help to arrange truly international PBL experiences, without the need for sponsoring travels and accommodation, hence leading to more sustainable educational activities. In addition, experts from all over the world can be invited as lecturers, keynote speakers and mentors, which increases the diversity and formative potential of these experiences. These virtual PBL experiences also place students in quite similar conditions to those from real-life within international engineering projects, in which a very relevant part of the interaction among project teams is enabled through online environments and thanks to Information and Communications Technologies.

Finally, in the authors' opinion, creating links between motivated and innovation-conscious students can be decisive in accelerating the transition to sustainable development in places like Africa. They have taken the first step and can continue to inspire other young people, generating a path of hope and irreversible transformation.

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References

1. A. D. Lantada and C. De Maria, Towards Open-Source and Collaborative Project-Based Learning in Engineering Education: Situation, Resources and Challenges, *The International Journal of Engineering Education*, **35**(5), pp. 1279–1289, 2019.
2. United Nations. Transforming our world: the 2030 Agenda for Sustainable Development. LXX General Assembly. New York, 2015. Available on-line https://sdgs.un.org/2030agenda, Accessed 28 June 2021.
3. United Nations. Sustainable Development Goals – Education https://www.un.org/sustainabledevelopment/education/, Accessed 28 June 2021.
4. A. M. Kaplan and M. Haenlein, Higher education and the digital revolution: About MOOCs, SPOCs, social media, and the Cookie Monster, *Business Horizons*, **59**(4), pp. 441–450, 2016.
5. P. Belleflamme and J. Jacqmin, An economic appraisal of MOOC platforms: business models and impacts on higher education, *CESifo Economic Studies*, **62**(1), pp. 148–169, 2016.
6. Y. Epelboin, MOOCs: A Viable Business Model?. In: Jemni M., Kinshuk, Khribi M. (eds) Open Education: from OERs to MOOCs. Lecture Notes in Educational Technology. Springer, Berlin, Heidelberg, 2016.
7. J. K. Silver, D. S. Binder, N. Zubcevik and R. D. Zafonte, Healthcare hackathons provide educational and innovation opportunities: a case study and best practice recommendations, *Journal of Medical Systems*, **40**(7), pp. 1–7, 2016.
8. Y. Zhao, COVID-19 as a catalyst for educational change, *Prospects*, 1–5, 2020.
9. J. Sinclair and S. Kalvala, Student engagement in massive open online courses, *International Journal of Learning Technology*, **11**(3), pp. 218–237, 2016.
10. M. Uffreducci, Hackathon as emerging innovation practice: exploring opportunities and challenges through 8 in-depth case studies, PhD Thesis, Politecnico di Milano, 2017.
11. E. M. Lepe and M. L. Jiménez-Rodrigo, Project-based learning in virtual environments: a case study of a university teaching experience, *International Journal of Educational Technology in Higher Education*, **11**(1), pp. 76–90, 2014.
12. C. L. Lin, The development of an instrument to measure the project competences of college students in online project-based learning, *Journal of Science Education and Technology*, **27**(1), pp. 57–69, 2018.
13. R. Yilmaz, F. G. K. Yilmaz and H. Keser, Vertical versus shared e-leadership approach in online project-based learning: a comparison of self-regulated learning skills, motivation and group collaboration processes, *Journal of Computing in Higher Education*, pp. 1–27, 2020.
14. K. Raghavan, S. Cohen-Regev and S. A. Strobel, Student outcomes in a local systemic change project, *School Science and Mathematics*, **101**(8), pp. 417–426, 2001.
15. D. Kokotsaki, V. Menzies and A. Wiggins, Project-based learning: A review of the literature, *Improving Schools*, **19**(3), pp. 267–277, 2016.
16. P. S. Cholifah, H. I. Oktaviani, N. L. S. Nuraini, A. M. Meidina, R. F. Wanodyaningtiyas and E. Yafie, Online Project-Based Learning for Improving the Innovative Initiation during Diffusion and Innovation Course. In *2019 5th International Conference on Education and Technology (ICET)* (pp. 55–60), IEEE, 2019.
17. Y. Lou and S. Kim MacGregor, Enhancing project-based learning through online between-group collaboration, *Educational Research and Evaluation*, **10**(4–6), pp. 419–440, 2004.
18. J. W. Lin and C. W. Tsai, The impact of an online project-based learning environment with group awareness support on students with different self-regulation levels: An extended-period experiment, *Computers & Education*, **99**, pp. 28–38, 2016.
19. P. Chanpet, K. Chomsuwan and E. Murphy, Online project-based learning and formative assessment. Technology, Knowledge and Learning, pp. 1–21, 2018.
20. A. Ahluwalia, C. De Maria and A. D. Lantada, The Kahawa Declaration: a manifesto for the democratization of medical technology, *Global Health*, **1**(1), p. 2, 2018.
21. UBORA Consortium, UBORA Platform https://platform.ubora-biomedical.org, Accessed 28 June 2021.
22. C. De Maria, L. Di Pietro, A. D. Lantada, A. Ravizza, M. Mridha, J. Torop and A. Ahluwalia, The UBORA E-Infrastructure for Open Source Innovation in Medical Technology. In Mediterranean Conference on Medical and Biological Engineering and Computing (pp. 878–882). Springer, Cham, 2019.
23. C. De Maria, L. Di Pietro, A. Ravizza, A. D. Lantada and A. Ahluwalia, Open-source medical devices: Healthcare solutions for low-, middle-, and high-resource settings. In Clinical Engineering Handbook (pp. 7–14). Academic Press. 2020.
24. The United Nations Economic Commission for Africa. Africa Innovation and Investment https://www.uneca.org, Accessed 30 March 2021.
25. The African Biomedical Engineering Consortium, ABEC, http://abec-africa.org, Accessed 30 March 2021.
26. The International Federation for Medical and Biological Engineering, IFMBE, https://ifmbe.org/, Accessed 30 March 2021.
27. Engineering for Change, E4C, https://www.engineeringforchange.org/, Accessed 30 March 2021.
28. Youth Innovators Competition and Design Bootcamp 2020 playlist. https://www.youtube.com/watch?v=6uxYHkMlOWE&list=PLfX97QdmyVmRJp-Ji8h__ym4qnQX8fleM, Accessed 30 March 2021
29. UBORA Consortium (2019). Compendium of innovation created through UBORA. https://ec.europa.eu/research/participants/documents/downloadPublic?documentIds=080166e5c6892d06&appId=PPGMS, Accessed 30 March 2021
30. L. Di Pietro, E. Botte, G. Granati, S. Moroni, M. Tomasi, G. Vozzi, and C. De Maria, C. Teaching Design Standards and Regulations on Medical Devices Through a Collaborative Project-Based Learning Approach, *International Journal of Engineering Education*, **35**(6A), pp. 1803–1815, 2019.
31. A. Ahluwalia, C. De Maria, A. D. Lantada, L. Di Pietro, A. Ravizza, M. Mannan and A. Leibovitš, Towards Open Source Medical Devices-Current Situation, Inspiring Advances and Challenges. In Biodevices (Vol. 1, pp. 141–149). Science and Technology Publications, 2018.
32. UBORA consortium. Youth Innovators Competition and Design Bootcamp 2020. http://ubora-biomedical.org/yicdb-2020-programme/, Accessed 30 March 2021
33. A. R. Bielefeldt, K. G. Paterson and C. W. Swan, Measuring the value added from service learning in project-based engineering education, *International Journal of Engineering Education*, **26**(3), pp. 535–546, 2010.

34. A. Ahluwalia, C. De Maria, J. Madete, A. D. Lantada, P. N. Makobore, A. Ravizza and J. Torop, Biomedical engineering project based learning: Euro-African design school focused on medical devices, *International Journal of Engineering Education*, **34**(5), pp. 1709–1722, 2018.
35. A. D. Owens and R. L. Hite, Enhancing student communication competencies in STEM using virtual global collaboration project based learning, *Research in Science & Technological Education*, pp. 1–27, 2020.
36. International Telecommunication Union. Measuring digital development Facts and figures 2019. International Telecommunication Union, Geneva, 2019. [available also on-line at https://www.itu.int/en/ITU-D/Statistics/Documents/facts/FactsFigures2019.pdf, Accessed 30 March 2021.
37. R. Zelezny-Green, 'Now I want to use it to learn more': using mobile phones to further the educational rights of the girl child in Kenya, *Gender & Development*, **26**(2), pp. 299–311, 2018.
38. V. Rotondi, R. Kashyap, L. M. Pesando, S. Spinelli and F. C. Billari, Leveraging mobile phones to attain sustainable development, *Proceedings of the National Academy of Sciences*, **117**(24), pp. 13413–13420, 2020.

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