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Hyper-connected hybrid educational models for distributed learning through prototyping

Modelo educacional híbrido hiperconectado para el aprendizaje mediante creación de prototipos

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Abstract

The emergence of virtual classrooms has deeply impacted and transformed the educational methodologies and protocols, in particular since the dawn of the COVID19 pandemic. This sudden change from on-campus to virtual learning spaces has also presented a unique opportunity to teach locally and reach globally. The following paper aims to present a pilot educational framework stimulating distributed learning through prototyping using remotely controlled mechanical systems, not only as a transitory state of educational programs moving to online programs due to the current pandemic but as a viable alternative.

***Keywords:** peer learning, education, cooperative, fabrication, and distributed.*

***Thematic areas:** design, digital fabrication, and circular economies.*

Resumen

La aparición de las aulas virtuales ha impactado profundamente y ha transformado las metodologías y protocolos educativos, siendo esta transformación acelerada debido a la pandemia de COVID19. Este cambio repentino de espacios de aprendizaje en el campus a virtuales también ha presentado una oportunidad única para enseñar a nivel local y llegar a nivel mundial. El siguiente artículo tiene como objetivo presentar un marco educativo piloto que estimula el aprendizaje distribuido a través de la creación de prototipos utilizando sistemas mecánicos controlados a distancia, no sólo como un estado transitorio de los programas educativos que se trasladan a los programas en línea debido a la pandemia actual, sino como una alternativa viable.

***Palabras clave:** aprendizaje, educación, cooperativo, fabricación, distribuido.*

***Bloques temáticos:** diseño, fabricación digital y economías circulares.*

1. Introduction

A shift towards online education has been taking place over the past decade, with online resources for education providing the opportunity to gain new skills at a level of accessibility that wouldn't have been possible for previous generations. The COVID-19 pandemic has made the virtual world a more central part of most of our lives, as lockdowns forced workplaces to be created in homes around the world. Subsequently, online learning models have become ubiquitous. Given the circumstances in most parts of the world, these platforms have proven to be quite effective. This reality hit the Institute for Advanced Architecture (IAAC) and the Fab Lab Barcelona on Monday 16th March 2020 when it was forced to close following the beginning of the state of emergency two days prior for the whole of Spain.

Prior to this shift, online educational models have established themselves as a reliable alternative to face-to-face classrooms and have given guidance to methodologies for successful alternative educational scenarios. Functional digital workflows can be rethought and introduced into the contemporary educational systems and integrate dimensions such as self-regulated learning. Online education has been built upon the strong foundation of distance learning. Though it may seem that distance education is a recent intervention into the educational field, its seeds date back as early as the 1900s. The concept of distance learning first came into practice in the mid 19th century when the US postal service was developed. The nation of reliable, long-distance correspondence led to the development and implementation of instructional documents that were distributed through the postal service between students and professors.

In 1858, the University of London offered the first distance learning degrees, expanding their outreach from nationwide to worldwide. Following the pioneering educational model, similar distance learning or correspondence courses were offered, enabling students to finish pursuing education at their own convenience. Formerly, online educational models have been considered to be an alternative to the lack of physical accessibility to educational institutions. In 1996, Jones International University became the first accredited and fully web-based university. Since the creation of these fully online programs, distance learning has picked up pace in many different countries. In 2003 the Blackboard Learning System staff announced that 40,000 instructors were teaching 150,000 online courses to more than 6 million students, across 55 countries. Elite institutions around the world now offer open courseware, online degrees, and online classes that are both legitimizing and popularizing the idea of education from a computer.

After the television, the personal computer, and the global world wide web were the next major inventions to revolutionize distance education. As communication technologies improved, allowing for real-time connected classrooms, online programs gained support from major educational centres, it wouldn't be wrong to predict that distance education will continue to expand and gain popularity in the future. As proven by the rise of Massive Open Online Courses (MOOCs) hosted through various platforms and embraced by notable research universities such as: edX(Duke, Princeton, and Stanford), Coursera (MIT ,Harvard, U of Texas systems), and Udacity(San Jose) In the simple case of Udemy, it has reached an astonishing number of over 35 million students in total. The ease of accessibility to this high volume of users could well impact society in many exceptional ways. Regardless of the fact that these educational models have proven successful, in their core they only rely on digital interfaces and their educational content only relies on theoretical subjects. This simplifies the initial requirements and processes as no specialised equipment is required. In digital fabrication educational programs the machinery and

equipment are essential as these programs rely on hands on and learning by doing methodologies.

The COVID-19 crisis made remote learning mandatory for schools, universities, and academies all over the world - as a case study during that period, students of Fab Academy Barcelona and the Master in Design for Emergent Futures (MDEF), had to change drastically their methodologies. Even though the Fab Academy program is already a distributed learning course, students watch weekly lectures from Neil Gershenfeld online connected to others on the Fab Academy network; the program had to evolve further to adapt to the lack of physical access to the fabrication laboratories. These courses are usually connected to a Fab Lab to allow students to have a hands-on experience with prototyping their designs using the machines, however, the labs were closed during that period which forced the academic institution to provide alternative solutions.

A global FabLab networked approach was to establish guidelines, documentation, curated lessons, and virtual workshops to compensate for the lack of physical access to the fabrication facilities. An example of this was the “UNPLUGGED Lesson Collection from Scopes-DF backed up from Fab Foundation. Various institutions have introduced remote fabrication aid. Examples of providing at-home machines and materials during seminars and workshops can be identified in the University of Washington, University of California Santa Barbara and NYU in the courses lead respectively by Nadya Peek, Jennifer Jacobs and Ben Light. Furthermore, as maker shop/ fabrication lab space simulation we could include Shelby Doyle and Mark Cutkkosky respective courses, at Iowa State and Stanford Universities as educators who experimented with immersive digital lab environments.

The global summer school (GSS) is another instance of an educational format that has evolved due to the COVID-19 pandemic. In editions prior to 2019, the workshops used to take place presentially in fabrication facilities all over the world. In 2021 the GSS network introduced a Remote Controlled Robots course that was focused on giving students around the world the chance to experience robotic fabrication processes.

In more detail the educational research group at Fab Lab Barcelona designed for that challenging scenario the ‘SPML Machine’ - otherwise known as the Simple-Personal-Mini-Lab and the “CNC by the Sea workshop” . The SPML was a low-cost open source mini CNC laser machine that students could fabricate at home with preproduction’s parts. The ‘CNC by the Sea’ was a modified CNC machine with remote control through the internet, that was set up by the research team at Fab Lab Barcelona for the students to access the machines remotely so that students can continue their hands-on projects remotely. The machine consists of a 3-axis machine modified to draw in a sandbox, in which students could input any design from their homes and view the designs being drawn via two webcam streams. The two machines were created out of a necessity for the students to be able to continue their learning whilst remaining safe during the COVID-19 outbreak. Amongst disruptive times, innovation often accelerates - these open source tools still are under continue usage in our ‘new normal’ society and are available for the Barcelona Fab Academy, Master in Design for Emergent Futures and anyone else who wishes to build their own ‘CNC by the Sea’ or SMPL.

Projects like the one discussed above have supplied new learning dimensions to the educational space. They provide a hyperconnected learning ecosystem that provides feedback whilst navigating between home and traditional educational facilities.

The educational field, hereafter, opens up to a broader range of telemetry tools to record necessary knowledge and transfer them through pedagogic programs, yet to deliver the content

via such programs in the midst of a pandemic is not straightforward. For students, a much higher amount of time is spent in front of the screen on calls which can be draining, and for faculty, there is a high level of coordination and planning necessary to adapt to a changing and unpredictable set of circumstances. On top of this, there is an added mental strain brought about by the confinement. A level of complexity is added when a lot of the content that normally is delivered in a hands-on in-person format which requires physical access to the lab for building prototype es and developing different competencies that relate to the physical world has to move online.

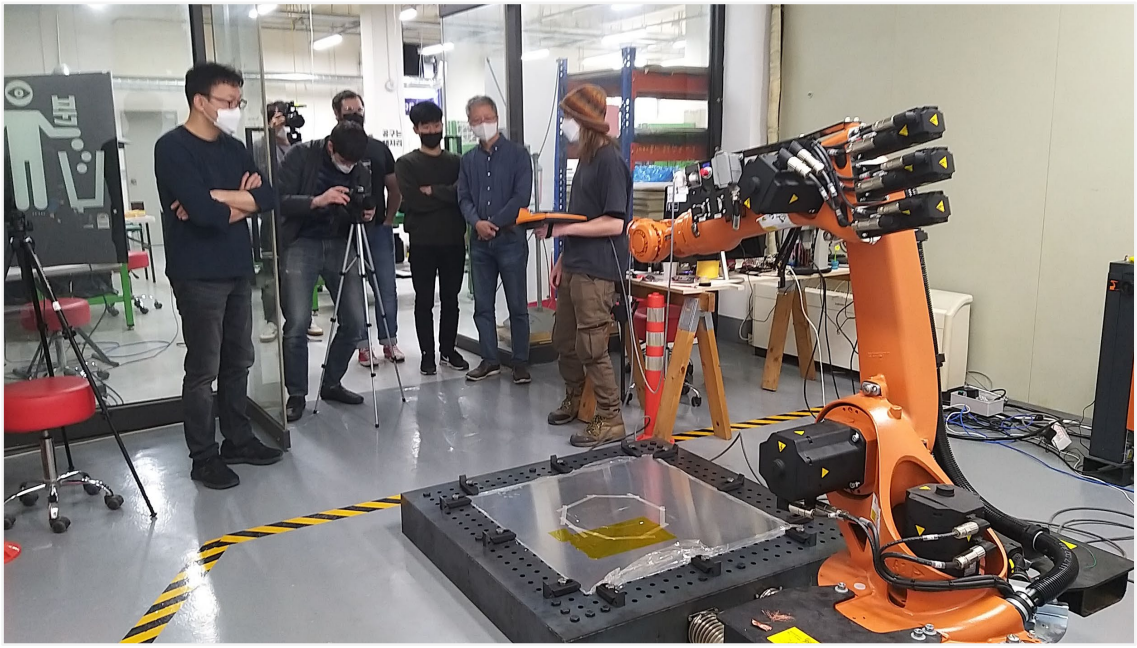

Fig. 1 Workshop setup at Seoul Innovation Lab (SIL)

The focus, therefore, has been to investigate how the course can prepare not just for the following academic year, but develop strategies and carry out a year-long intensive research exercise into the hybrid and distributed learning experiences with the possibility of its permanent implementation. One key goal was to identify the ways in which a hybrid model approach is not merely a replacement for a full physical format of delivery, due to the pandemic's restrictions, but a viable alternative that adds value to an overall learning experience as well as to create an open-source toolkit of distributed learning practices focused on design and maker communities.

This article's purpose is to demonstrate the ongoing research over these past few months concerning the topics deployed above. More specifically, the article contains: the future learning framework, the research methodology and documentation tools developed by the team as well as an important case study of a subject of digital fabrication curriculum that provided valuable insights regarding hybrid and distributed learning approaches and finally the conclusions and takeaways gathered so far.

2. Research Scope

The end of the academic year in 2020-21 in July provided a peculiar period of reflection on what could be learned from the months of distributed learning in order to plan for the next academic year, having in mind the potential levels of disruption that could take place. During this period, the team was able to transition from preparation for educational programs and courses in an “emergency-remote learning” method to a “hybrid learning” mindset which refers to planning and establishing mixed educational models both remote and local simultaneously, specifically in designing courses.

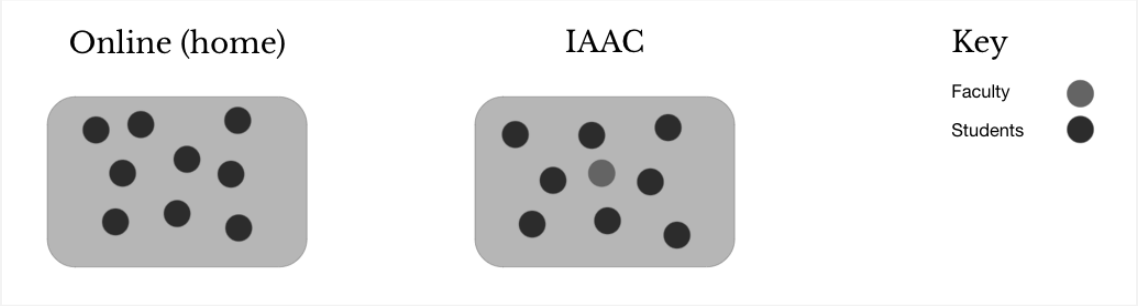

Diagram. 1 Hybrid Learning classroom mixed scheme

The framework was tested during a workshop with the collaboration of two educational and applied research institutes, namely, the Institute of Advanced Architecture for Catalonia, Spain (IAAC) and Seoul Innovation Lab (SIL), aiming to provide knowledge transfer on plastic recycling and robotic fabrication. A key objective is to identify the ways in which a hybrid model approach is not merely a replacement for a full physical format of delivery but a viable alternative that adds value to an overall learning experience, as well as to developing remote teaching methodologies for distributed learning practices focused on design and hands-on practices such as 3d printing, industrial robots, and plastics recycling processes.

2.1 Why Hybrid

The Hybrid model refers to the different class formats included in a hybrid learning environment whether it's in-person, online, or a combination of in-person and online. The purpose of the Hybrid model research is to enrich and potentially reform the guide, transforming it into a toolkit that can be used and adapted to similar hybrid learning courses in the future. There are a number of reasons why you may want to carry out a hybrid style class over a fully distributed one, to list a few;

- Bi-lateral communication
  - Direct feedback can help develop social bonds between faculty and students & create a sense of belonging to both the group at class and university level
- Learning by doing
  - Optionally, students will have access to infrastructure and resources they won't have at home in terms of techniques and materials
- Extend capabilities
  - Non-verbal communication - students have access to the recorded sessions over and over again in case of doubts.

2.2 Why Hyperconnected

In the second phase, the participants were inducted into the Hyper-connected setup wherein they were guided through the digital-to-physical workflows from virtual tutorials and implemented them locally with the support lab assistants in person. The pace of the workflow was based on the fabrication knowledge acquired during the prior phase and experimented with scaled prototypes to test the fabrication techniques. The workshop concluded with the production of final 1:1 scale printed object.

This format poses several challenges from an educational structure point of view: not only do the different topics proposed through the development of the workshops demand their own dedicated learning strategy, but these need to be interwoven to make the fragments of knowledge - given asynchronously - complement each other.

2.3 Hyperconnected Hybrid model

The Hyperconnect Hybrid (HH) model refers to both the phase together where students have the theoretical knowledge of available mechanical systems from phase I and hands-on experience from phase II under the supervision of the locally present lab assistants. The virtual tutors are virtually connected to the lab machines to remotely program them through the developments happening in person. The HH model also promised lead over safety where each code generated to run on the robot went through two stages of check-up, once from the virtual tutors and secondly from the lab assistants before running the codes.

Through the use of Information communication technology (ICT), the workflow allowed multiple students to work simultaneously and have feedback from different tutors on respective aspects of the tutorial.

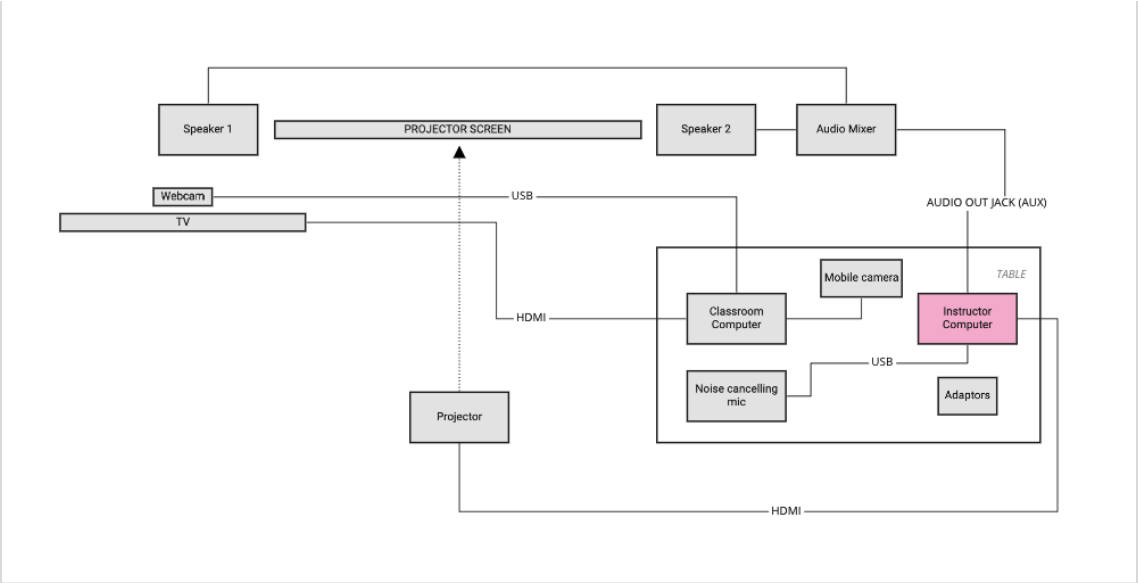

Diagram. 2 Layout of ICT tools used during the 'Recycling and 3D printing of plastics from city waste' workshop

The framework discussed in this paper from now on is the "Hyperconnected Hybrid model": a mixed classroom format where faculty is online and students are in part in person together with faculty assistants and in part remotely connected. The HH model of the workshop allowed for greater reach and transfer of knowledge, as well as improving faculty and student engagement. In order to ensure constant communication between the remote instructors and students during the practical sessions, the local instructors focused on consolidating and verifying that the knowledge was properly acquired during the hands-on sessions, and provided onsite guidance during physical prototyping.

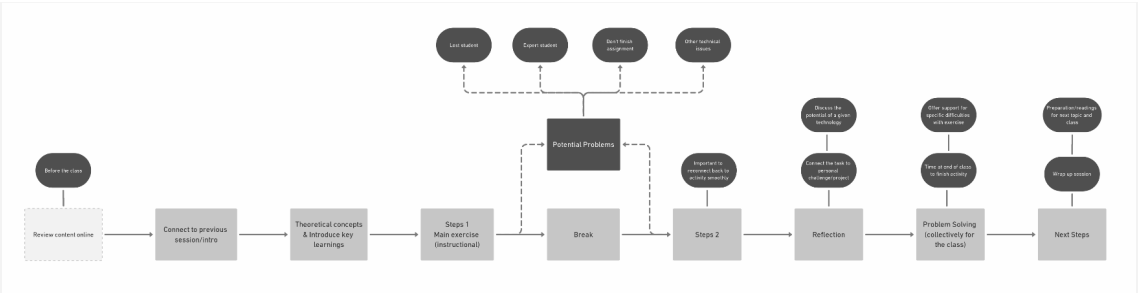

Diagram. 3 Classroom timing methodology followed during the workshop in Hyperconnected Hybrid model

2.4 Case Study

The framework was tested during an empirical and intensive two-week program in 'Recycling and 3D printing of plastics from city waste', where the setup consisted of an industrial robot with a plastic pellet extruder mounted on it. The workshop was designed to fill knowledge gaps between the host institutes and explore the possibilities of those technologies whilst testing alternative practice-based teaching methods, as opposed to the traditional remote master class format.

Fig. 2 Students attending the class screen videoconferencing system during the workshop time at Seoul Innovation Lab (SIL) / Fig.3 Faculty hyper-connected to the remote classroom with a videoconferencing system at the Institute of Advanced Architecture of Catalonia (IAAC-FABLABBCN)

This approach was subdivided into different interaction modes. The term interaction modes are used to define the different types of possible formats of delivery and how they are experienced within both online and hybrid learning environments. This refers mostly to the interaction between the tutor and the students and expresses the different ways in which learning can take place. These interaction modes include:

- Presentation mode
  - One-directional lecture
  - Instructor shares screen
  - No interaction from students
- Workshop mode
  - Hands-on activity
  - Prototyping with robot

- Discussion mode
  - Group class discussions
  - Includes students presenting work
  - Troubleshooting
- Studio mode
  - “Connected” working - students working on a task independently or in groups.
  - Instructor/Facilitator available to answer questions

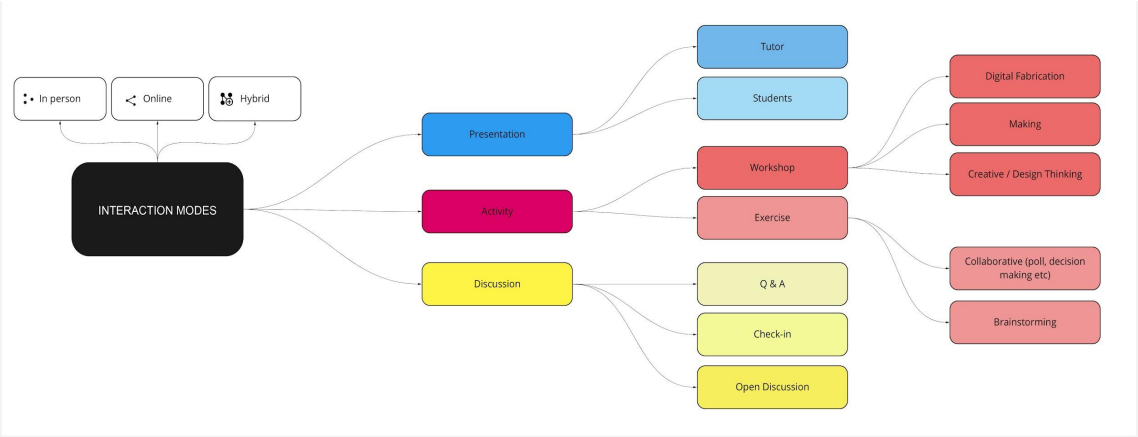

Diagram. 4 Layout of interaction modes methodologies used in the workshop

3. Problems and Challenges

As the course progressed we inevitably encountered several challenges concerning the hands-on hybrid class. “One of the first problems to emerge was the difficulty for the hybrid groups to communicate during class due to the noise from the surrounding environment. Since four out of five groups contained remote students and they all needed to discuss their ideas simultaneously via zoom, it inevitably resulted in confusion and annoyance generated by the chaotic and noisy classroom.” Due to this, some students demanded another classroom where they could isolate themselves for a period of time to discuss. Therefore, the team had to coordinate and come up with a quick solution, asking for the availability of another space at the institution facilities. The noise factor, even though in retrospect seems rather obvious, was not a parameter we took into consideration when planning the class and is, hence, one of the most valuable insights for planning hybrid practical workshops.

The instructor’s team had to, in a sense, compromise the premises of the final outcome to ensure that the essence of the learning objectives remained intact without overstressing and exhausting the students. This course, more than anything, accentuated the importance of establishing strong communication diodes between faculty and students in view of forging a reciprocal relationship that serves both the objectives of the course but also the needs and emotional stability of the learners. It also emphasized the significance of a flexible and adaptive learning strategy especially when dealing with complex courses such as cross-disciplinary robotics and 3d printing

Even though the content given through the remote connections was theoretical to be further applied on local hands-on experiences, the tutor implemented various different interaction modes and creative exercises for the students to be as engaged as possible. The presentations were visually engaging, incorporating a combination of various mediums including text, videos, gifs, and audio. The level of engaging content really helped the students to actively participate, which is especially important when a large amount of time is spent in front of screens and reduced mobility due to COVID.

In order to ensure constant communication with instructors and students during the practical class, breakout rooms were created for each group, and the teaching assistant was focused on transferring the instructor from room to room. Another assistant was physically present during the class in order to help with the hands-on prototyping.

4. Conclusion and Contribution

The research that has been carried out thus far with regards to the HH model for practice-based education provides valuable insights on distributed learning approaches. The case study discussed only represents a small explanatory probe similar to other courses tested before and there have been insights collected from all of the classes and workshops that have taken place due to the research methodology set out at the beginning of previous academic terms.

At this time, we have still been able to draw some insights relating to the research methodology, interaction modes, and general design strategies for creating learning experiences. Some of these have already been highlighted in the case studies but can be differentiated in online and hybrid insights. Among the online insights, the most significant include; the need for a carefully planned change of interaction modes along with the workshop from “Presentation” to “group discussion” to “activity” to grab the student’s attention permanently and maintain engagement. The mayor needs to not exceed the predetermined timeline of the class due to delays. To give students the opportunity to present their work to the class and get feedback from tutors and classmates. It is important for them to see their classmate’s work as well as the integration of collaborative/sharing tools (google Docs where students share bibliography etc, miro) and use them to do small creative tasks connected to the course (brainstorming, small exercise, thought experiment). Last to allow the students to explain the knowledge they have gained at the beginning and through the class.

Among the Hybrid insights the most significant include; The need for meticulous planning of the infrastructure needed for the class, including a key factor in that as a noise-cancelling speakerphone, screen, cameras with different perspectives to the classroom to let the communication and human interaction be the most immersive as possible. Special care and preparation must be taken to ensure the learning experience of the remote students. Improving the communication between the students and faculty frequently doing check-outs from the faculty asking both remotes and non-remote students on how they are feeling and how the group work is proceeding When Forming hybrid working groups the remote students must be evenly distributed according to their skill set. Otherwise, it is possible that they feel like they can’t contribute equally to the project since not being physically in the lab is already a disadvantage. Along with the different insights gathered in hybrid methodologies, flexibility and adaptability concerning the course’s instructional design are key aspects. A Hybrid class is a more complex learning environment where several challenges and technical problems can emerge. Designing a course that can adapt to these challenges without sacrificing its objectives is important as well as keeping constant communication with students during the course and being able to adjust according to their needs.

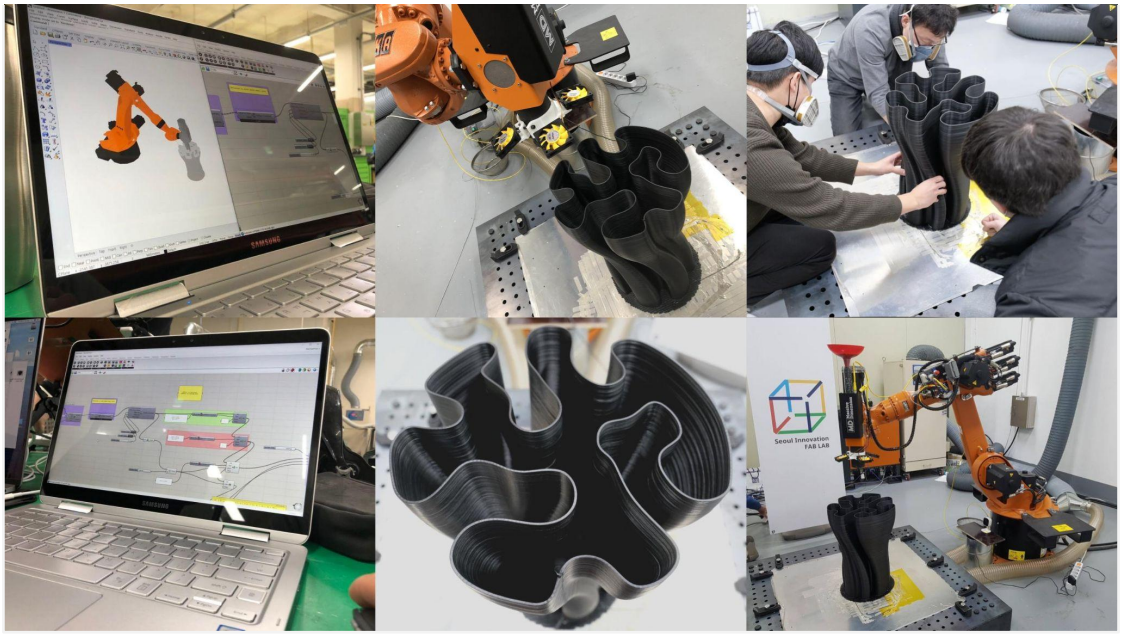

Fig. 4 Series of images showing students prototyping using Hyperconnected Hybrid model for digital fabrication of city recycled plastic

When approached as a mixed model, online learning, both synchronous and asynchronous, can result in educational experiences that do not merely compensate for the lack of physical interactions but exceed them by providing a space where students can concurrently develop autonomous design thinking behaviors. This allows for improved team interaction as the dependency on the individuals grows together with the knowledge acquired in a controlled and established education environment. The majority of the students were engaged and followed through with all of the course challenges. The research demonstrates that the initial limitations arising from remote educational models in relation to practice-based learning can potentially be balanced out or even overcome depending on the context of the course, approach, and embedded interaction modes, if properly adapted through its methodologies.

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