Can challenge-based learning be effective online? A case study using experiential learning theory

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ORIGINAL ARTICLE

Can challenge-based learning be effective online? A case study using experiential learning theory

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ABSTRACT

The COVID-19 outbreak had a major effect on moving online learning activities, also traditionally experiential ones such as those designed upon Challenge-Based Learning (CBL) principles. This article explores the impacts produced on a Challenge-Based Innovation project work carried out in the context of a program developed by Politecnico di Milano and Politecnico di Torino. A survey of 92 students and interviews were carried out to assess the impact on learning outcomes and processes, and four main success factors were identified: informal interaction, time for exploration, asynchronous lecturing, relevant challenges. Suggestions for an effective design of online CBI-like programs are offered.

Keywords: Challenge-based learning; design thinking; CBI; online learning; experiential learning; self-determined learning.

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INTRODUCTION

The coronavirus disease 2019 (COVID-19) outbreak forced learning activities to migrate online at an unprecedented rate, including activities that were traditionally believed to be effective only if carried out in person. Being experiential learning a collaborative process in which knowledge development is a social process (Blair, 2016) and concrete experience is needed (Kolb, 1984), not few doubts arise about the effectiveness that typically experiential approaches like Challenge-Based Learning (CBL) could have when delivered online. This made the "digital transition" of formats based on the principles of CBL, like the courses inspired by Challenge-Based Innovation developed at CERN ("CBI-like" programs), urgent and interesting to study.

The aim of this article is to assess the online transition of this kind of programs through the lenses of Kolb's experiential learning model (1984). Applying its concepts to a real case is a way to provide a solid framework to this study and contributes in turn to reinforce the experiential learning theory by bringing much needed fresh empirical foundation (Morris, 2019). Notwithstanding a bunch of studies apply Kolb's theories to online learning (e.g., Shamsuddin & Kaur, 2020), there is still scant literature studying this applied to CBL activities.

In the setting of a program designed upon the concepts of CBI-like programs, our research questions aim to explore whether and how an online version of CBL might affect its learning outcomes and processes. Since the dynamics through which this change occurs need clarification, with our first research question we investigate them to identify the major success factors that can make online versions of challenge-based activities experiential and effective. The second research question concerns which learning outcomes are more subject to be altered in the resulting new learning process of online challenge-based programs.

THEORETICAL BACKGROUND

Moving lessons online during the COVID-19 pandemic had contrasting effects; some scholars found positive impacts on student engagement, though negative on social interaction and personal connections (Craig et al., 2020), reducing communication channels compared to traditional "live" environments (Goh et al., 2020). Online learning is associated with greater geographical flexibility, economic accessibility for students, and is believed to be suited for passing theoretical notions (Owens, 2012).

Experiential learning

On the other hand, such "no real need of being in person" might lead to miss vital parts of the learning process described in the experiential learning theory (Kolb, 1984; Sadler-Smith, 1996; Morris, 2019). According to it, effective learning is a process of knowledge creation by grasping and transforming experience in a four-phase cycle: Concrete Experience (CE), Reflective Observation (RO), Abstract Conceptualization (AC), and Active Experimentation (AE). Depending on which phases an individual exploit best to learn, four main learning styles are identified: Divergers (CE+RO), Assimilators (RO+AC), Convergers (AC+AE), and Accomodators (AE+CE) (Fig. 1). No style has better academic performance than the others (Shamsuddin & Kaur, 2020), but assessing them can be an important driver for designing educational programs (Tratnik et al., 2019).

Challenge-based learning

Among the approaches exploiting concrete experience to foster learning, Challenge-Based Learning (CBL) has received increasing attention by researchers in recent years. CBL aims at inspiring students to solve a "real-life" complex problem relevant to their context (Pérez-Sánchez et al., 2020), "the challenge". Students perform loops of analysis, and eventually propose an actionable solution to their trainers (Nichols & Cator, 2008). Technology must be part of the proposed solution, however not necessarily implying the realization of an artefact (Membrillo-Hernández et al., 2018; (Pérez-Sánchez et al., 2020). CBL incorporates 21st-century skills (Nichols & Cator, 2008; Shuptrine, 2013) into Problem-Based Learning, a curricular active learning approach with which it shares features as being student-centred, promoting interest in design and technology, and enhancing teamwork, collaboration, problem-solving and communication skills (Allen et al., 1996; Silberman, 1996; Duch et al. 2001; Johnson et al. 2009; Jou et al. 2010; Membrillo-Hernández et al. 2018).

CBI-like programs

With their focus on technology and relevant challenges, CBL activities can generate innovation (Gallagher & Savage, 2020). Emblematic are the "Challenge-Based Innovation" (CBI) courses carried out at CERN (Kurikka et al., 2016), focused on design-thinking approaches and user-centred design (Palomäki, 2019). Several activities, inspired by CBI in their main principles, have begun to be carried out in other institutions. In such "CBI-like programs", students of different disciplines follow project-based teaching structures and collaborate in multidisciplinary, distributed, and international teams, to solve innovation challenges by translating fundamental technological research into societal applications (Dym et al., 2005; Kurikka et al., 2016; Jensen et al., 2018). CBI-like programs tackle innovation challenges from the perspectives of business, technology and people (Charosky et al., 2018), and are structured into the Double-Diamond Design Thinking process (Technology Strategy Board & UK Design Council 2005) consisting of *Discover* (diverging), *Define* (converging), *Develop* (diverging) and *Deliver* (converging) phases.

Self-determined learning

The idea for which a student can actually learn from CBI-like programs is grounded in the idea of self-determined learning, or "heutagogy", according to which students – if adequately motivated and engaged to actively participate – are responsible for directing their own learning of 21st-century skills by sharing and generating knowledge in peer-to-peer team-based learning environments (Blaschke & Hase, 2016; Fisher et al., 2020). Hence, CBI-like programs do represent a way to learn by grasping and transforming experience. However, the learning dynamics for which this could happen effectively also in online-learning settings are still unexplored in literature, and it would be highly beneficial for practitioners to identify the key success factors that could foster the diffusion of effective digital versions of CBI-like programs, and Challenge-Based Learning at large.

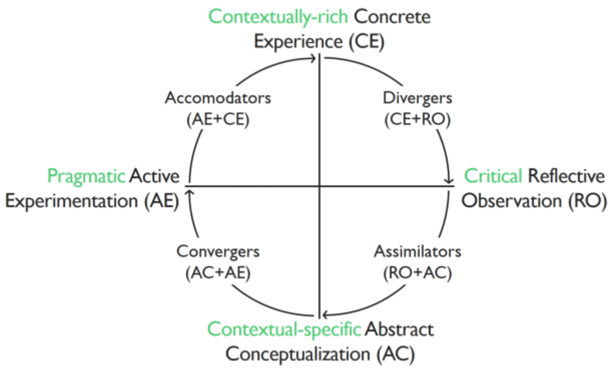

Fig. 1. Experiential learning cycle phases and styles, adapted from Kolb (1984) and Morris (2019).

METHOD AND DATA

The program

The empirical setting is the Alta Scuola Politecnica (ASP), an honors program jointly developed by two major Italian technical universities (Politecnico di Milano and Politecnico di Torino), involving every year 150 selected freshmen of their Engineering, Architecture, and Design MSc courses. The focus on innovation and technology, along with the heterogeneity of student background disciplines and nationalities, are key aspects of this program. Throughout the two years, the students attend four short intensive one-week courses (the "ASP Schools"), characterized by (i) didactics delivered through academic-level lectures and interventions of expert practitioners, and (ii) a team-based innovation project work developed with the logics of CBI-like programs. Guided by professors and PhD students as tutors, the competing teams are asked to tackle a relevant challenge by exploring its complexity and constraining objectives, and the state of the art of a specific edge technology (*Discover*), synthetize them to identify the opportunity areas (*Define*), and come up with a technology-based actionable solution (*Develop*) to be presented on the last day (*Deliver*).

The online school

Due to the COVID-19 outbreak, the fourth and last School of the 2019-20 class had to be held remotely. As a consequence, some changes were done with the aim of stimulating interest and motivation, keeping the same workload while avoiding a five-day full time immersive course, recreating part of the live interactions, and matching the schedules – overturned by the pandemic – of either professors, tutors, and students.

Therefore, the challenge – initially thought as the exploitation of Digital Twins (i.e. those technologies that enable a seamless integration between the physical and the cyber spaces, see Tao et al. 2018 for a detailed reference) for smart buildings, manufacturing and health – was re-contextualized around the pandemic, to explore innovative solutions "to react to, and learn from, the COVID outbreak". The five-day project work was diluted into four weeks, with weekly instead of daily deliverables. The tutor-student constant informal interactions had to be turned into scheduled meetings. In a flipped-classroom approach, videos of theoretical lectures were made available (asynchronous lecturing), and the masterclasses were set up in form of online (synchronous) round-table meetings.

Data collection

To explore the differences between offline and online Schools *learning processes*, i.e., the first RQ, ten interviews were collected, until theoretical saturation (Yin, 2009) was reached. The semi-structured interviews, with a length ranging from 30 to 45 minutes each, focused on asking the students how they approached each of the four learning cycle's phases differently from the three previous Schools held in person. The interviews were recorded, transcribed, and coded inductively into aggregate dimensions, following the approach proposed by Gioia et al. (2013).

Also, a survey was issued right after the School, answered by 92 out of the 120 students. To triangulate findings with the qualitative data, the students were asked to provide positive and negative open comments on the online School compared with the previous three they had attended in presence.

The other main purpose of the survey was to answer to RQ2, by assessing what *learning outcomes* were most affected by the online version. A 1-5 Likert scale was used for the self-determined assessment about acquiring knowledge, skills and attitudes that build up competency (e.g., Banathy, 1968) related to innovation, i.e. the desired learning outcomes. Students were also asked what they would have learned better in a "live" School. The investigated items are shown in Fig. 4: knowledge items are related to digital twins and business models to exploit them; skills and attitudes – given the focus on innovation and team-based dynamics – were drawn from the P21 framework (see Partnership for 21st Century Skills 2009 for detailed information). Also, with the aim of providing additional insights on the experiential learning phases, we used the Kolb LSI-3 (1999) tested measurement scale to cluster the students by learning style and ANOVA to determine statistically significant differences among them, which we fully report in the Annex.

RESULTS

1. Coding of the interviews

Four aggregate dimensions emerged from the interviews coding (right side of Fig. 2), representing the major differences that had an impact on the four phases of the experiential learning cycle. Following, we report some illustrative examples of the whole data collected.

Virtual interaction

The shift from the Reflective Observation (RO) to the Abstract Conceptualization (AC) phases – usually enabled by the simultaneity of project work activities and interaction with tutors – was felt harder by the students. The "formality" of virtual interaction was its most reported limitation. The immersiveness of the live format, which used to enable the generation of "weak ties" and informal learning, was missed a great deal in the online format:

> "Once, I was in a group with some computer engineers and, as I was sitting next to them, they were explaining me a programming language, R. I learned it just by being close to them. This time, everyone did 'their own part', but we couldn't see it."

> "Offline there are other dynamics, things you can discover by chance: you walk in the classroom, see what other groups are doing, talk with them, and you have learned something."

Decompressed timing

The diluted schedule allowed to explore more in detail the teaching contents, enabling RO and AC more than in the compressed five-day format, thus allowing the conception of more complex and complete solutions:

> "We had more time to think and reflect. One of the girls in our group could talk with her father, who had experience in that specific field, and gave us an input and an idea: having more time was good, it allowed us to explore and understand more."

> "[…] time was diluted, so you have more time to think about things. In offline schools you have little time, you have the urgency to deliver something so don't even think too much. In this case we had time to think

> and reason individually, discuss together, even better than in a physical school."

Mixed lecturing

Concerning didactics, the students found beneficial the possibility to replay the lectures when needed, exploiting them as support for the RO phase; on the other hand, the synchronous lectures did not motivate the students to participate:

> "The recorded lessons were very useful, because we also had the possibility to review some concepts that were not very clear to us."

> "I feel I learned less, this time, because there was little incentive to attend those online masterclasses of the professionals. […] I perceived this lack of incentive, that turned into lack of participation."

Motivation and involvement

Last, the students felt overall a lack of involvement. One thing that partially contributed to restore motivation was the highly interesting and topical challenge. This worked as a proper CE of the continuous learning cycle, enabling RO phase through motivation:

> "I felt very involved with the project work, especially for the topic. It was helpful because it touched us closely. Doing the project work on something real, more than usually, was very useful and we liked it."

> "In my opinion, such a current topic allowed us to have very specific ideas since the beginning. Usually, ideas are very general in the Schools, nobody knows much about them. Instead, […] everyone had their opinion about COVID and reasoned about it."

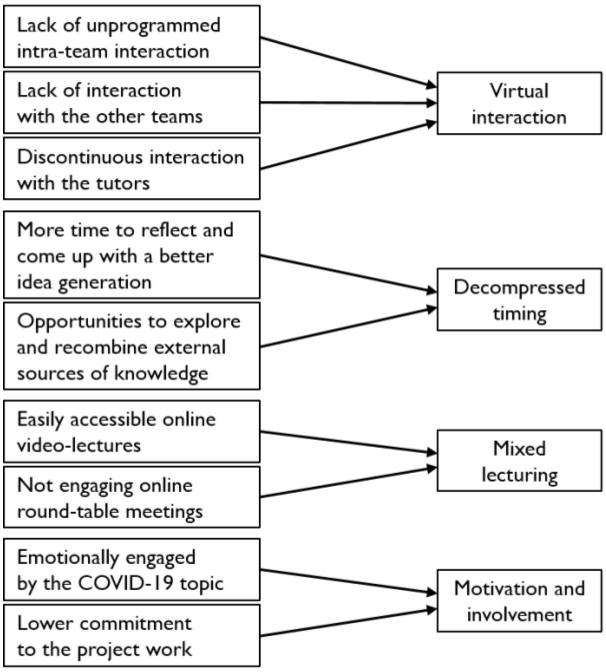

Fig. 2. Coding into aggregate dimensions (Gioia et al. 2013).

2. Main results from the survey

Figure 3 shows that virtual interaction and motivation and involvement were critical according to most of the students' negative comments, whereas references to decompressed timing and mixed lecturing were found especially among the positive ones. Fig. 4 shows how most of the students indicated that collaboration (68%), along with social and cross-cultural interaction (55%), were the main skills that they feel they would have improved more if the activities were held in person, whereas digital skills and theoretical knowledge were the less affected by the online version. Concerning theoretical notions, statistically significant differences were found among learning styles, and opposite patterns concerning the two main knowledge areas of this CBI-like program: digital twins (technology) and business models (innovation). For example, Accomodators and Divergers – who need CE to learn – struggled more in acquiring concepts related to digital twins as a hands-on prototyping was not envisaged, but benefitted of being engaged by the concrete pandemic challenge in acquiring concepts related to business models aimed at developing innovative solutions. The full analysis assessing the rest of the items is reported in the Annex.

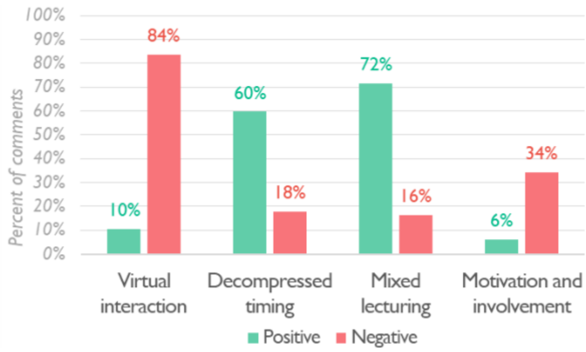

Fig. 3. Occurrence of references to the four identified aggregate dimensions in the open comments.

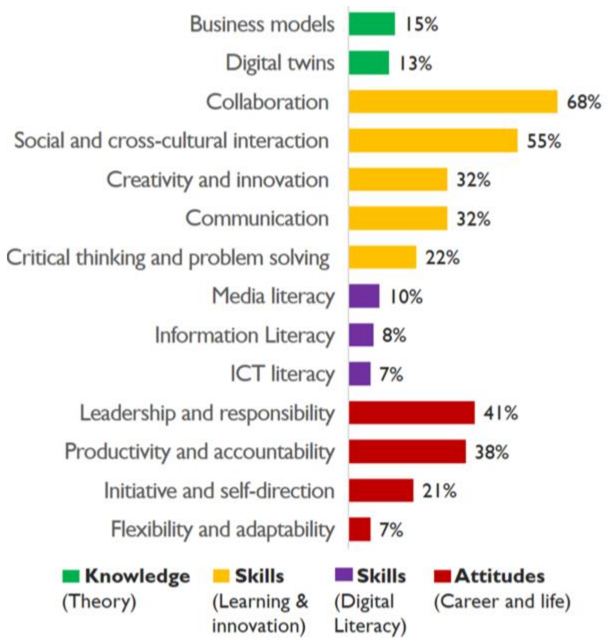

Fig. 4. Percentage of students stating that the 14 analyzed competency items would have been acquired better in presence.

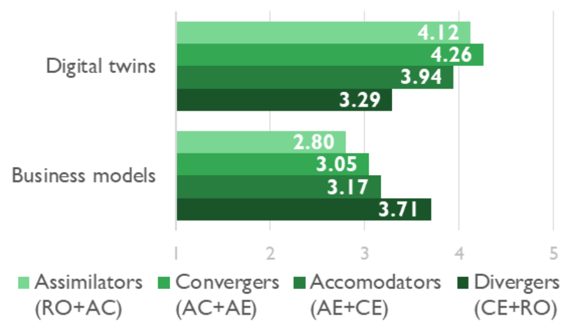

Fig. 5. Perceived learning outcomes concerning the two main knowledge areas (1-5 Likert scale: 1=low; 5=high).

DISCUSSION AND CONCLUSIONS

The disruption in formality of interaction, use of time, type of lecturing, and the relevance of the topic, had major and specific impacts on learning outcomes and processes. Triangulating qualitative and quantitative data allowed to draw the following considerations and recommendations.

Contrarily to the promising results of Goh et al. (2020) about developing team-working skills in online projects, these were the most affected ones. The weaker interactions with teammates, professors and tutors resulted in less opportunities for informal learning (Gama et al., 2018) as confirmed by the 84% of students' negative comments on virtual interaction. Therefore, interaction must be ensured for those who need brainstorming to foster creativity, and "supervised" for whom might tend to avoid interaction. When possible, face-to-face meetings in an inspiring space should be envisaged, especially in the diverging phases of CBI (Jensen et al., 2018).

The online team-based format allowed the students to combine and synthesize various perspectives (as in Goh et al., 2020), and the decompressed four-week schedule (compared to one week) was found positive by 60% of the students as it empowered conceptualization. Therefore, specific versions of CBI-like programs could be compressed in 4-week intensive formats, but probably not less than that.

The flexibility provided by a mixed lecturing was appreciated (72% of positive comments). Asynchronous lecturing proved to be effective for passing theoretical knowledge, whereas more engaging formats of synchronous interaction need to be thought of. Here, the use of breakout rooms and active learning techniques could incentivize participation and provide more fruitful learning opportunities.

Last, working on a challenge of current interest played a key role: students felt more involved and felt they were working on something practical and real: the "contextually rich" concrete experience envisaged by Morris (2019). Indeed, while some students (e.g. Accommodators) need "hands-on" activities, others (e.g. Divergers) need concrete and topical challenges to feel motivated to learn.

Our results have implications for designing the contents and the schedule of online CBL that balance the stages of the experiential learning cycle:

- reproduce moments of casual interaction in the *observation* phase to enable informal learning;
- allow enough time for the *conceptualization* to draw knowledge from external sources;
- make the *experimentation* as hands-on as possible;
- envisage a topic that is perceived as relevant and of interest, for a truly "contextually-rich" *experience*.

Also, our results encourage educators to assess the learning style mix of the class in advance, to prioritize these design efforts accordingly in case of constraints in time and/or resources. A major limitation of this work could be the relative inexperience of professors, tutors and students with online environments, thus further empirical studies will be interesting to determine whether learning economies affect these results, by testing longitudinally empirical parameters of learning.

To conclude, Challenge-Based Learning initiatives such as CBI-like programs can be effective online, and their diffusion needs to be fostered in the post-COVID redesign of education, especially concerning innovation. Such programs could even be the most effective ones to engage and motivate students remotely, and enable self-determined learning, as long as the activities are designed to activate all the stages of learning and accommodate – or challenge – all types of learners.

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ANNEX

[A] Kolb's Learning Style Inventory

With the aim of maximizing the comparability with previous literature, the Kolb LSI-3 (1999) tested measurement scale was selected to cluster the students according to their learning style. This leads to the categorization of students into four learning styles: Divergers, Assimilators, Convergers, and Accommodators.

[A1] "Please rank the endings of each sentence based on how well they describe your way of learning. Put 4 next to the statement that BEST describes you, 3 to the second best, 2 to the third best, and 1 next to the statement that worst suits you."

- [A1.1] When I learn:
    - I like to deal with my feelings.
    - I like to watch and listen.
    - I like to think about ideas.
    - I like to be doing things.
- [A1.2] I learn best when:
    - I trust my hunches and feelings.
    - I listen and watch carefully.
    - I rely on logical thinking.
    - I work hard to get things done.
- [A1.3] When I am learning:
    - I have strong feelings and reactions.
    - I am quiet and reserved.
    - I tend to reason things out.
    - I am responsible about things.
- [A1.4] I learn by:
    - feeling.
    - watching.
    - thinking.
    - doing.
- [A1.5] When I learn:
    - I am open to new experiences.
    - I look at all sides of issues.
    - I like to analyze things, break them down into their parts.
    - I like to try things out.
- [A1.6] When I am learning:
    - I am an intuitive person.
    - I am an observing person.
    - I am a logical person.
    - I am an active person.
- [A1.7] I learn best from:
    - personal relationship.
    - observation.
    - rational theories.
    - a chance to try out and practice.
- [A1.8] When I learn:
    - I feel personally involved in things.

  - I take my time before acting.
  - I like ideas and theories.
  - I like to see results from my work.
- [A1.9] I learn best when:
  - I rely on my feelings.
  - I rely on my observations.
  - I rely on my ideas.
  - I can try things out for myself.
- [A1.10] When I am learning:
  - I am an accepting person.
  - I am a reserved person.
  - I am a rational person.
  - I am a responsible person.
- [A1.11] When I learn:
  - I get involved.
  - I like to observe.
  - I evaluate things.
  - I like to be active.
- [A1.12] I learn best when:
  - I am receptive and open-minded.
  - I am careful.
  - I analyze ideas.
  - I am practical.

Divergers (CE to RO – feeling and watching) perform better in concrete situations where different points of view, creativity and inventive activities are needed; Assimilators (RO to AC – thinking and watching) logically process information, think and reason rather than interacting with people; Convergers (AC to AE – thinking and doing) search practical uses for theories through technical problem solving and decision making; Accommodators (AE to CE – feeling and doing) need hands-on experience and trust their gut feelings. Each of the answers is associated to a learning style, following a coded table. The four scores are summed up (minimum score = 12 if a style is always selected as least preferred, maximum score = 48 if style always selected as most preferred), and the student is assigned to the learning style that obtained the highest score.

[B] Perceived learning outcomes: knowledge and 21st century skills (P21 Framework)

[B1] Please indicate the extent to which you agree or disagree with the endings of the following statement (1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree). "In this School..."

- [B1.1] I improved my critical thinking and problem solving skills
- [B1.2] I am now more fexible and adaptable
- [B1.3] I improved my ability to find, retrieve, analyze, and use information
- [B1.4] I acquired theoretical knowledge about digital twins
- [B1.5] I improved my communication skills
- [B1.6] I am now more productive and accountable
- [B1.7] I now have more initiative and self-direction
- [B1.8] I improved my ability to use digital technology, communication tools, and/or networks
- [B1.9] I improved my social and cross-cultural interaction skills
- [B1.10] I acquired theoretical knowledge about business models
- [B1.11] I improved my collaboration skills
- [B1.12] I acquired leadership and responsibility
- [B1.13] I improved my ability to access, analyze, evaluate and create messages in a variety of for (print, video, Internet…)
- [B1.14] I improved my creativity and innovation skills

[C] Perceived learning outcomes: offline vs online

[C1] Please indicate the extent to which you agree or disagree with the endings of the following statement (1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree), multiple answers allowed. "Which of the previous items would you have acquired better if the school had been held in presence?"

- [C1.1] Critical thinking and problem solving
- [C1.2] Flexibility and adaptability
- [C1.3] Ability to find, retrieve, analyze, and use information
- [C1.4] Theoretical knowledge about digital twins
- [C1.5] Communication
- [C1.6] Productivity and accountability
- [C1.7] Initiative and self-direction
- [C1.8] Ability to use digital technology, communication tools, and/or networks
- [C1.9] Social and cross-cultural interaction
- [C1.10] Theoretical knowledge about business models
- [C1.11] Collaboration
- [C1.12] Leadership and responsibility
- [C1.13] Ability to access, analyze, evaluate and create messages in a variety of forms (print, video, Internet…)
- [C1.14] Creativity and innovation

[C2] Please list (up to) 3 negative aspects of this online version of the challenge compared to the in-presence version
[C3] Please list (up to) 3 positive aspects of this online version of the challenge compared to the in-presence version

Results

The four learning styles, computed through the answers to Section A, were all represented in the sample (45.7% Convergers, 27.2% Assimilators, 19.6% Accommodators; 7.6% Divergers), allowing to perform the desired statistical analyses. The results were used in the article as follows:

- Answers to [C2 and C3] used in Fig. 3
- Answers to [Section C1] used in Fig. 4
- The answers to [Section A] and [Section B] were used in Fig. 5 in the article, as an extract from Tab. I (see below). Statistically significant differences were found among the clusters, e.g. Divergers felt they acquired collaboration skills and business models knowledge better than Assimilators, but less knowledge on digital twins than Assimilators and Convergers.

Tab. I. Perceived learning outcomes by learning style

KSA	Learning outcomes	Mean	St. Dev.	Div (CE+RO)	Ass (RO+AC)	Con (AC+AE)	Acc (AE+CE)
Knowledge *(Theory)*	*Business models*	3.05	1.12	3.71**	**2.80**	3.05	3.17
	Digital twins	4.09	1.06	**3.29**	4.12*	4.26***	3.94
Skills *(Learning & innovation)*	*Collaboration*	3.67	1.14	4.29*	**3.44**	3.81	3.44
	Social and cross-cultural interaction	3.04	1.12	2.86	2.88	3.24	2.89
	Creativity and innovation	3.52	1.13	3.29	3.36	3.67	3.50
	Communication	3.25	1.12	3.14	3.00	3.29	3.56
	Critical thinking and problem solving	3.33	1.09	3.43	3.16	3.24	3.72
Skills *(Digital Literacy)*	*Media literacy*	3.21	1.19	3.00	3.12	3.43	2.89
	Information Literacy	3.28	1.17	3.43	3.12	3.26	3.50
	ICT literacy	3.16	1.12	3.43	3.00	3.31	2.94
Attitudes *(Career and life)*	*Leadership and responsibility*	3.40	1.12	3.71	3.28	3.43	3.39
	Productivity and accountability	3.09	1.07	3.00	3.08	3.05	3.22
	Initiative and self-direction	3.05	1.23	3.29	2.92	2.93	3.44
	Flexibility and adaptability	3.52	1.07	3.71	3.48	3.50	3.56

*Note: mean values in 1-5 Likert scales. Statistically significant differences, evaluated through ANOVA, are those between the figures in bold and the figures with stars (*p < 0.10; **p <0.05; ***p <0.01)*