Student-centered personalization of individual education through Reusable and Autonomous Learning units - the SPIRAL model

STUDENT-CENTERED PERSONALIZATION OF INDIVIDUAL EDUCATION THROUGH REUSABLE AND AUTONOMOUS LEARNING UNITS - THE SPIRAL MODEL

Sorana Cimpan
University of Savoie Mont-Blanc
sorana.cimpan@univ-smb.fr

Francesco Floris
University of Turin
francesco.floris@unito.it

Marina Marchisio Conte
University of Turin
marina.marchisio@unito.it

Sergio Rabellino
University of Turin
sergio.rabellino@unito.it

ABSTRACT

The COVID-19 pandemic acted as a catalyst, accelerating the transition to e-learning worldwide. Educators and students swiftly transitioned to online teaching and learning platforms as educational institutions closed their doors to curb the spread of the virus. A key trend in Education 4.0 is personalized learning, ensuring that the pace, content, and delivery methods are adapted to maximize individual growth and achievement, thereby increasing the effectiveness of student-centered learning environments. Personalization at scale is only possible through technology. Intelligent e-learning systems enable personalized learning by dynamically tracking and managing the learning needs of all students. These systems provide a platform that delivers a wide range of engaging learning content, resources, and opportunities, accessible anytime, anywhere, far beyond the confines of a traditional classroom. However, in parallel with technology, teachers and their role in the learning design process play an essential role in effective personalization. In this article, we therefore present the model we have developed for online course design that seeks to converge two models (that of adaptive learning platforms and that of competency-based learning). The model fits into the design phase of a classic ADDIE educational design cycle and proposes a strategy for the macro-design of the course. This model also aims to standardize the metadata available for learning units, making finding and sharing learning materials easier. This uniformity is crucial for applying comparison algorithms to personalize the learning experience for students. The model is currently undergoing testing and validation.

KEYWORDS

Online Course Design; Personalized Learning; SPIRAL model; Student-centered learning.

1. INTRODUCTION

The COVID-19 outbreak in early 2020 has impacted education at an unprecedented level, and almost all educational institutions worldwide have had to completely move to online education (Banihashem et al., 2023). The COVID-19 pandemic acted as a catalyst, accelerating the transition to e-learning across the globe. With educational institutions forced to close their doors to curb the spread of the virus, educators and students quickly adapted to online platforms for teaching and learning. This shift highlighted the importance of digital literacy and revealed the potential of e-learning to provide flexible and accessible education. As a result, many institutions and individuals have invested in technology and digital infrastructure to enhance the e-learning experience, paving the way for more widespread adoption of online education even beyond the pandemic era. The University of Turin has considerable experience in the creation of online courses. The Orient@mente initiative was launched in 2015 with the objective of assisting students in the transition

between secondary school and university through a platform that enables them to interactively explore the study paths proposed by the University (Barana et al., 2017a, Barana et al, 2017b). In 2018, Start@Unito was established as a selection of university modules in a broad range of topics, administered through open online courses that are freely available. These courses could also be used to facilitate the transition between secondary and tertiary education and to enhance success in higher education (Marchisio, Operti et al., 2019, Marchisio et al., 2020). During the pandemic, numerous practices emerged to ensure continuity of education in student-centered learning environments (Otto et al., 2024). An analysis of the cycle of visioning, planning, and implementing learner-centered ecosystems in teaching-learning can be found in Patey's work (Patey, 2023). One of the nine crucial trends identified by Patey in Education 4.0 is personalized learning: "*Education 4.0 emphasizes learner-centered learning through `flipped' or `blended' learning modes, in which students can choose the content and courses they want based on their needs, to help them explore their skills and abilities*" (Patey, 2023). The design of a course is fundamental to effectively personalize learning. A well-structured course framework allows for the incorporation of diverse learning styles, paces, and preferences, ensuring that each student can engage with the material in a way that suits them best. By thoughtfully integrating adaptive learning technologies, varied instructional methods, and flexible assessments, course design can address individual needs and promote a deeper, more meaningful understanding of the subject matter. This tailored approach not only enhances student engagement and motivation but also maximizes educational outcomes by recognizing and nurturing the unique potential of every learner. To make this approach possible, it is essential to use Learning Analytics techniques to monitor, evaluate and eventually modify the learning path of individual students (Floris et al., 2020, Marchisio et al., 2019; Fissore et al., 2023). The role of learning analytics is also very important in blended learning, and it is necessary to inform and raise awareness among teachers on this topic (Bournaveas et al. 2022). This article proposes a design model for online courses and their content. The model aims to provide a way for collecting and analyzing the data required for effective personalization of learning. It also aims to provide teachers with a common design methodology, enabling them to share information, collaborate on course implementation, and highlight any design problems. In the next section, the concepts of student-centered learning, personalized learning, and an overview of recommendation models and systems will be presented with their connection to the instructional design practices. To understand teachers' perceptions of learning design, we conducted an international survey, the results of which are presented in the section “Teachers' perspectives on learning design”. This analysis is based on data collected through 3 questions in a questionnaire administered to participants of the online course "INVITE training module," which was developed within the context of the INVITE project (https://invite-erasmus.eu/). The SPIRAL model will thereafter be introduced, without going into too much detail, focusing on the main entities and main aspects that its application can have, both for students and teachers. A testing and validation phase of the model is currently in progress. The concluding section, on the other hand, will give space for future developments of this work.

2. STUDENT-CENTERED AND PERSONALIZATION OF LEARNING

Student-centered learning is an educational approach that places students' needs, interests, and learning styles at the core of the learning process. It emphasizes active learning, where students engage in activities, discussions, and projects that foster more profound understanding and critical thinking (Wright, 2011; Overby, 2011). This approach is closely connected to personalized learning, which tailors educational experiences to individual student’s strengths, weaknesses, and preferences (Patey, 2023). By focusing on each student's unique path, personalized learning ensures that the pace, content, and delivery methods are adapted to maximize individual growth and achievement, thereby enhancing the overall effectiveness of student-centered learning environments. Beese gave another definition of personalized learning: "*Educational personalization is best conceived, in a broad sense, as what occurs in any process that uses information from or about a student to generate plans or educational decisions for that student*"(Beese, 2019). One theory that describes the design characteristics of personalized learning is that of Walkington and Bernacki. This theory focuses on how a learning environment can be modified to benefit students' cognitive, motivational, and affective processes that influence their learning. In this theory, three dimensions relevant to learning theories are identified, based on which personalized learning strategies can vary. The first dimension is the “variable degrees of depth”, which measures how much the daily life experiences of students affect the

design of teaching activities. The second dimension, called “different grain sizes”, is the granulometry of the personalization intervention, which can be at the level of the individual student, of small groups (with one or more common characteristics) or of larger groups based on more general parameters. The third dimension is “ownership”, that is the degree in which students are given control and choice of learning situations (Walkington et al., 2014). Wolf (2010) stated that technology also enhances personalized learning: “*Personalization cannot take place at scale without technology. Personalized learning is enabled by smart e-learning systems, which help to dynamically track and manage the learning needs of all students and provide a platform to access myriad engaging learning content, resources, and learning opportunities needed to meet each student’s needs everywhere at any time, but which are not all available within the four walls of the traditional classroom*.” In their review work, Otto S. and his colleagues (Otto et al., 2024) identify three technological models to support personalized learning: *Open Digital Badges* – offer personalized learning by allowing students to choose badges relevant to their competence level, prior knowledge, and progress; *Competency-Based Learning* - enables learners to progress by mastering competencies aligned with their prior knowledge, skills, and abilities (an example of application is reported in Pasterk et al, 2022); *Adaptive Learning Platforms* - create personalized learning pathways by analyzing students' responses to lessons and assessments, thereby providing tailored resources and learning materials; this way, class time can be used for discussions and extending learned material.

In particular, for the last model, the related instructional design theory refers to learning objects. The term "learning object" is often used interchangeably with "learning material", “learning resource” or “educational resource”. The Learning Technology Standards Committee uses the term learning object to describe small instructional components: "*Learning Objects are defined here as any entity, digital or non-digital, which can be used, reused, or referenced during technology-supported learning. Technology-supported learning includes computer-based training systems, interactive learning environments, intelligent computer-aided instruction systems, distance learning systems, and collaborative learning environments. Examples of Learning Objects include multimedia content, learning objectives, instructional software and software tools, and persons, organizations, or events referenced during technology-supported learning*." (LTSC, 2007). David Wiley (Wiley, 2002) defines a learning object (LO) as any digital resource that can be reused to support learning, emphasizing its digital nature. He also created a taxonomy of LO types and listed characteristics to distinguish them, with the aim of differentiating types for instructional design. Wiley employs the metaphor of famous compostable bricks game to illustrate LOs. He posits that small instructional pieces can be assembled into larger structures (e.g., castles) and reused in new configurations (e.g., spaceships). However, unlike the bricks, not all learning objects (LOs) can be easily combined. Another metaphor Wiley employs is that of the atom, representing LOs as small units that can be combined to form larger entities. This metaphor highlights granularity and combination properties yet leaves unresolved issues. Granularity pertains to the minimum size of an LO, which is likened to subatomic particles forming atoms. Establishing this minimum size is, however, necessary. Furthermore, the combination issue remains to be clarified, as Wiley's taxonomy needs to address how LOs can be effectively combined explicitly. However, in line with what Bruschi and Perissinotto stated in their work (Bruschi, Perissinotto, 2003), there may be problems using learning objects to design online courses. One of the most complicated points is that there is a certain autonomy in terms of the structure and the amount of knowledge that each learning object must contain. In this way, however, the creation of customized pathways, even in an automated way, although possible given the technological progress achieved, would result in internally very diverse and uneven pathways. Furthermore, another possible problem is the amount of work the teacher requires to design a single learning object, considering all the metadata that would need to be defined. It is not surprising that in the literature of the last few years, there is a large amount of work on teachers' perceptions of online teaching and the use of technology (An et al., 2021; Hassan, 2020). The various studies reveal that while teachers recognize the potential value of technology and online/blended learning, they feel they need more time to make a complete transition and prefer traditional teaching. One of the points on which many teachers agree is that creating e-content takes more time and effort than classroom teaching (Hassan, 2020). On the other hand, the literature should focus on teachers' perceptions of learning design strategies and their implementation and effectiveness. A survey was therefore conducted in order to gain insight into teachers' perceptions of design practices and to gain an overview of which aspects they consider most relevant in design practice. The results of this survey will be presented in the next section.

3. TEACHER'S PERSPECTIVES ON LEARNING DESIGN

The INVITE (Developing Competencies and Innovative Designs for International Virtual and Blended Modalities) project aims to enhance teaching and learning competencies for designing and implementing new virtual and blended modes of international collaboration within European Higher Education Institutions (https://invite-erasmus.eu/). Despite the rapid response of many institutions to the educational challenges posed by the COVID-19 pandemic, there is now a collective understanding among EU Member States of the need to develop further and integrate virtual and blended learning modalities post-pandemic. In alignment with the European Commission's Digital Education Action Plan 2021-2027, the INVITE project seeks to support educators in acquiring digital skills to improve the quality of digital practices in education. The project also emphasizes the development of new Erasmus+ Blended Intensive Programs, in line with the Green Agenda's support for internationalization efforts. The INVITE project addresses various challenges associated with digitalization in higher education, aiming to create a robust educational foundation for the future. Focusing on student-centered approaches and active learning, the project aims to promote a more inclusive and effective digital education environment in Europe (Barana & Marchisio, 2024).
One of the results of this project is a new training module for higher education teachers and staff to promote the activation of virtual and blended international learning activities. One of the first steps during the training program is an initial questionnaire (in two versions, one for teachers and one for staff), in which three questions are related to the course design. We included these questions (and some in the final questionnaire) to explore teachers' perceptions of learning design. The training program started in the second half of April. Registration was free and open to all; over 1000 users signed up for the course. The registration form asked the user to indicate which of the two categories the user feels most similar to teacher or staff member. In order to choose the correct training path, the following definitions were present in the module: Teachers (or educators) are people interested in developing digital international teaching and learning activities; the staff members want to create international bridges among institutions and support teachers and/or students in developing or implementing digital international activities. We decided to analyze the three questions on learning design, and so far, we have the answers from 124 teachers and 47 staff members. The first question was "*Do you have experience in course design?*". There is little difference between teachers and staff, as only 55% of teachers have experience in course design and 36% of staff members. Then we asked teachers and staff members who answered *yes* to the following question: "*On a scale from 1 to 5, where 1 represents minimal planning, and 5 represents comprehensive planning, please indicate how thoroughly you typically design the following aspects of an online course*", and the results are reported in Fig. 1 and Fig. 2. The results show that teachers who claim to have experience in course design focus mainly on the course structure and learning outcomes, while not thoroughly structuring the prerequisites. The same attitude is reflected in the behavior of the staff. This second result was entirely predictable, as the creation (and therefore planning) of individual materials and evaluation is usually more associated with the role of the teacher. What is surprising, however, is a certain disregard for the role of prerequisites.

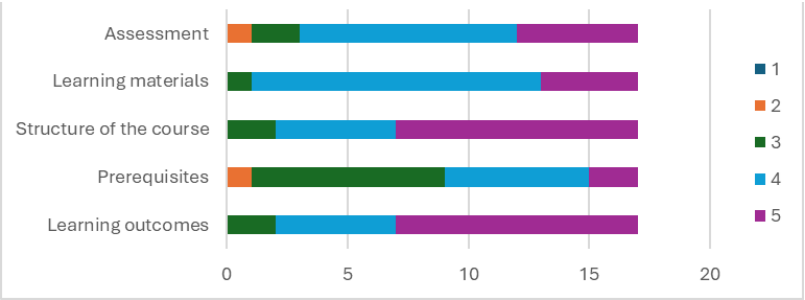

Fig.1 – Answers from the staff members to the question n.2

The lack of focus on prerequisites stems from the fact that students' pathways are usually placed in a broader context, and therefore, many teachers somehow think that they come naturally. However, for effective adaptation, it is essential to correctly and in-depth outline the aspects related to the prerequisites. In the final question, which was also asked of those participants who answered *yes* to the first question, we asked what tools and/or software they use for course design. The survey shows that almost 50% of people in each group

do not use specific tools and/or software. The responses vary significantly from those who say they use them, and most do not indicate fundamental course planning/design tools. For example, some mention Moodle (about 25% in both groups) or h5p, but these are tools for creating and using content, not designing it. In fact, only one person included in the group of staff members stated that he or she uses a specific tool for learning design (the ABC learning design model). The fact that the instructional design is clearly perceived as an important aspect, combined with the almost inexistent use of tools to support this design highlights the need and opportunity for proposing effective support for instructional design. This is one of the main goals of the SPIRAL model we propose in the following section.

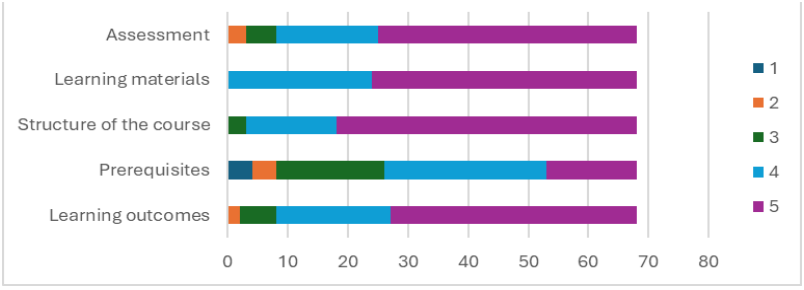

Fig.2 – Answers from the staff members to the question n.2

4. SPIRAL MODEL

In an attempt to integrate the two models discussed in section 2 (competency-based learning and adaptive learning platforms), we developed a new model, the SPIRAL model, for designing digital learning courses based on a new type of object: the learning unit. SPIRAL stands for ***S****tudent-centered* ***P****ersonalization of* ***I****ndividual education through* ***R****eusable and* ***A****utonomous* ***L****earning* units. The principal objective of the model is to identify and formalize all entities and their relationships in order to facilitate personalized learning for students. Furthermore, it seeks to provide teachers with both a methodology and a tool to design online courses and teaching units, thereby simplifying their work and also helping to identify potential problems in course design. The design phase can be divided into macro-design and micro-design, with one following the other. The macro-design phase defines course outcomes, target audience, content, and learning units. During the micro-design phase, designers create learning activities, assessment methods, and instructional materials for every designed learning unit. The model proposed here focuses on the macro-design phase. The standardization of metadata associated with teaching units aims to to facilitate the search and sharing of learning units. Furthermore, this uniformity is essential for the application of comparative algorithms that can automatically propose personalized learning experiences for students. The "SPI" part of the acronym refers to student-centered learning, which places the student at the heart of the learning process. This approach allows students to decide both what materials to learn and how to learn it. These decisions involve two levels of content customization: a general level and a specific level. At the general level, recommendation systems suggest courses to students based on their aptitudes, preferences, and past experiences, which is a significant area of research. Once a topic has been chosen, there are various possible learning paths at the specific level. Each path, composed of a sequence of learning units, is designed to achieve the same learning outcomes through different means. This model proposes a structure for these units that allows for comparison and highlights differences, enabling students to choose their preferred path and retain control over their learning process. The second part of the acronym highlights the key characteristics of these learning units. Each learning unit is connected to a specific single learning outcome, defining the learning pathway by a set of outcomes. Students can choose the units they wish to use to achieve these outcomes. The R part emphasizes that learning units should be reusable, meaning they can be applied in different contexts. The A part indicates that the units should be autonomous and self-contained, allowing them to function independently of their context. This modular design approach ensures flexibility and adaptability. In the next section we will focus on the entities and the idea behind the model, analyzing the advantages we can derive from it for both teachers and students.

4.1 Learning Outcomes and Learning Units

The first entity that we define is *Learning Outcomes (LO)*. We started with the definition of learning outcomes given in the "European Quality Framework 2017" (European Commission, 2008): "[. . .] statements of what an individual should know, understand and/or be able to do at the end of a learning process, defined in terms of knowledge, skills and responsibility and autonomy", but we added some descriptors. Basically, in our model, when we talk about learning outcome, we mean an object represented by:

- The sentence that represents the learning outcome. This sentence will consist of "Verb + Object". In our case, the verbs are selected from the verbs associated with a particular level of Bloom's Taxonomy. The second part of the sentence is the object of the verb.
- Topics. Compared to the object previously declared, the topic defines a more general topic that can be inserted from a hierarchical topic structure.
- The level of Bloom's Taxonomy
- The type of Learning Outcome (parent or child) in the context in which the Learning Outcome is defined.

There are two types of learning outcomes. The first type are *macro-LOs*, which refer to the level of the whole online course. They answer the question "*What will learners be able to do when they have completed the course?*". The second type are *micro-LOs*, which refer to the level of the learning units in the learning pathway and answer the question "*What will learners be able to do when they have completed this unit?* ". The main reason for this distinction is that macro-LOs can only be assessed indirectly because they are too broad. However, we can construct a learning path made up of micro-LOs that will enable them to be acquired. To emphasize this difference, we have chosen to use the parent-child relationship of the many-to-many type. A clear implication of this classification is that it is inherently contextual.

The fundamental concept of our model is the *Learning Unit* (LU), whose definition is derived from Wiley's definition of learning object (Wiley, 2002), but has many points in common with the definition of "Autonomous Learning Object" given in (Bruschi, 2003). A learning unit is a collection of three types of digital learning materials: resources, activities, and summative assessment. When a learner completes a learning unit, he/she acquires one and only one learning outcome. In order to be sure that a learner has acquired a learning outcome, a summative assessment is a mandatory component of a learning unit.

Starting from this definition, we have identified all the descriptors necessary for each learning unit to define a learning pathway and, simultaneously, to make them comparable: Title - a short title of the Learning Unit; Description - a short description of the Learning Unit; Prerequisite (0+) - prerequisites are learning outcomes that define the basic knowledge required to access the LU. It can be 0 or more; Outgoing Learning Outcome (1) - we use Bloom's taxonomy to indicate the Learning Outcomes: ECTS - this is the time allotted for study in order to complete the learning unit; Scale of difficulty - the teacher can indicate here the estimated the difficulty for this LU. We use the term *Learning Path (LP)* to denote a structured and sequenced progression of Learning Units designed to guide individuals through the process of acquiring a Learning Outcome. This sequence of LUs is constructed starting from the LU to which the LO is associated and, recursively, adding all the learning paths necessary to acquire the prerequisites of that learning unit. We can therefore extend the relationships and characterizations introduced for LO and LU also to learning paths, such as a measure of path difficulty, a measure of interactivity or even an expected completion time. The formalization introduced allows us to calculate a measure of similarity between Learning Outcomes which can be exploited for the generation of alternative learning paths, with a dual meaning. On the one hand, in fact, if two Learning Outcomes are similar, we can say that their respective learning paths are equivalent, in the sense that following one or the other makes no difference in terms of learning outcome acquired. On the other hand, since the prerequisites are also defined as Learning Outcomes but seen as "input", the similarity can be exploited to create a sequence between learning units. In this way it is not necessary to define a specific path a priori for each student but to show each student all the possible learning paths to acquire an appropriate learning outcome, with all the information to make an informed choice about which path to follow. In this way, going back to the 'ownership' dimension of (Walkington et al., 2014), the control of the Learning Units to be followed is entirely in the hands of the individual student. Furthermore, all the information collected by the system can also be used to identify possible problems in the design phase. For example, when we think about macro and micro learning outcomes, an important consideration is that the level of a macro learning outcome must be higher than or equal to that of its child LOs when referring to Bloom's Taxonomy. An LO can only be of a lower level if all its children are of different themes. In this case, it is worth considering how and to what extent knowledge of different topics at an advanced level can

provide skills and knowledge in another topic. These discrepancies can be analyzed automatically to identify possible gaps in the course design. Another crucial aspect to consider is that the formalization introduced allows for the sharing of information, which, in a community of practice of teachers/educators, can be leveraged to utilize the learning units even outside the context in which they are defined. This also facilitates their sharing. To achieve this, it is essential to prioritize autonomy, ensuring that the units are self-contained and contain all the necessary contents, activities, and evaluation tools to function and integrate seamlessly in another context.

5. CONCLUSION AND FUTURE DEVELOPMENTS

Implementing a student-centered approach in higher education has the potential to yield significant and far-reaching consequences. This paradigm shift fosters a more engaging and interactive learning environment, encouraging students to participate actively in their education. Individual needs and preferences are better met by introducing personalized learning pathways, thereby promoting equity and inclusion. To realize customized courses at individual units within a curriculum and across entire programs, we have developed a SPIRAL model that defines the entities involved and their relationships. Our model revolves around the learning unit, a structured collection of digital learning materials, including resources, activities, and summative assessments. Each learning unit leads to a specific learning outcome, aligning with the European Quality Framework 2017. The model utilizes descriptors such as title, description, prerequisites, learning outcomes, estimated learning time, and difficulty defining and comparing learning units. We can create personalized learning paths by establishing relationships between these units, such as prerequisite connections. Instead of prescribing a specific path for each student, our approach presents multiple pathways, allowing students to choose their preferred route to achieving the desired learning outcomes. The model's data collection capabilities also help identify potential gaps and discrepancies in course design, ensuring a cohesive and comprehensive learning experience. In conclusion, this model aims to provide a flexible and adaptable design methodology for online courses that meet the needs of different learning contexts, like BIPs, COILs, and MOOCs. The model is currently undergoing an extensive phase of testing and validation to ensure its accuracy, reliability, and performance before it is deployed for use. Building on the SPIRAL model, we are developing an online editor to collect, organize, and utilize educational data. This editor will be integrated with existing learning management systems (LMSs), creating a unified platform where teachers can create, manage, and adapt the content in real time based on individual student needs. Leveraging advanced data analytics, the editor will monitor student progress, engagement, and performance, providing valuable insights that enable educators to refine instructional strategies and materials, thus better supporting each student's journey.

ACKNOWLEDGEMENT

The research activity described in this paper has been carried out within the Erasmus+ K.A.2 N. KA220-HED-2021-006 “Developing Competences and Innovative Designs for International Virtual and Blended – INVITE” and within the GNSAGA group of INDAM – “Istituto Nazionale di Alta Matematica F. Severi”.

REFERENCES

An, Y., Kaplan-Rakowski, R., Yang, J., Conan, J., Kinard, W. and Daughrity, L., 2021. Examining K-12 teachers’ feelings, experiences and perspectives regarding online teaching during the early stage of the COVID-19 pandemic. *In Educational technology research and development*, 69, pp. 2589-2613.

Barana, A., Marchisio, M., Bogino, A., Operti, L., Fioravera, M., Rabellino, S. and Floris, F., 2017a. Self-paced approach in synergistic model for supporting and testing students. *Proceedings of 41st Annual Computer Software and Applications Conference (COMPSAC)*, Vol. 1, pp. 407-412.

Barana, A., Bogino, A., Fioravera, M., Marchisio, M., & Rabellino, S., 2017b. Open Platform of self-paced MOOCs for the continual improvement of Academic Guidance and Knowledge Strengthening in Tertiary Education. In *Journal of e-Learning and Knowledge Society*, *13*(3), pp. 109-119.

Barana A. and Marchisio Conte M., 2024. Eight Sustainable Practices for Digital Activity Development: Drivers and Barriers in International Higher Education Collaboration. In *Computer*, vol. 57, no. 03, pp. 117-122.

Beese, E. B., 2019. A process perspective on research and design issues in educational personalization. *In Theory and Research in Education*, v. 17(3), pp. 253–279.

Bournaveas, V., Gueye, M., Cimpan, S. and Exposito, E., 2022. Penser l'hybridation avec l'appui des Learning Analytics: l'approche HyPE 13 pour la formation des enseignants. *In Questions de pédagogies dans l'Enseignement Supérieur*, pp 1-19.

Bruschi, B. and Perissinotto, A. 2003. *Come creare corsi on line*. Carocci, 2003.

da Silva, F. L., Slodkowski, B. K., da Silva, K. K. A. and Cazella, S. C., 2023. A systematic literature review on educational recommender systems for teaching and learning: research trends, limitations and opportunities. *In Education and Information Technologies*, 28(3), pp. 3289-3328.

European Commission, 2017. Council recommendation on the European qualifications framework for lifelong learning and repealing the recommendation of the European Parliament and of the Council of 23 April 2008 on the establishment of the European qualifications framework for lifelong learning. Official Journal of the EU.

Fissore, C., Floris, F., Marchisio, M. and Rabellino, S., 2023. Learning analytics to monitor and predict student learning processes in problem solving activities during an online training. *Proceedings of 47th Annual Computers, Software and Applications Conference (COMPSAC)*, pp. 481-489.

Floris, F., Marchisio, M., Sacchet, M., and Rabellino, S., 2020. Learning Analytics to Evaluate the Effectiveness of Higher Education Student Failure Prevention. In *International Association for Development of the Information Society*, pp. 265-272.

Hassan M. M., Tabasum M. and Mirza, W. H., 2020. A critical review by teachers on the online teaching-learning during the COVID-19. *In International Journal of Education and Management Engineering*, pp 17–27.

Kazem Banihashem, S., Noroozi, O., den Brok, P., Biemans, H. J.A. and Taghizadeh Kerman, N., 2023. Modeling teachers' and students' attitudes, emotions and perceptions in blended education: Towards post-pandemic education. *In The International Journal of Management Education*, Volume 21, Issue 2, pp. 1472-8117.

LTSC, Learning Technology Standards Committee. The learning object metadata standard, 2007, available at https://www.ieeeltsc.org/working-groups/wg12LOM/lomDescription/

Marchisio, M., Operti, L., Rabellino, S, and Sacchet, M., 2019. Start@unito: Open online courses for improving access and for enhancing success in higher education. *In Proceedings of the 11th International Conference on Computer Supported Education*, pp. 639-646.

Marchisio, M., Rabellino, S., Roman, F., Sacchet, M. and Salusso, D., 2019. Boosting up data collection and analysis to learning analytics in open online contexts: an assessment methodology. *In Journal of E-learning and Knowledge Society*, 15(3), pp. 49-59.

Marchisio, M. and Sacchet, M., 2020). Analysis Items to Assess the Quality of Open Online Courses for Higher Education. In *International Association for Development of the Information Society*, pp. 63-70.

Otto, S., Bertel, L. B., Lyngdorf, N. E. R., Markman, A. O., Andersen, T. and Ryberg, T., 2024. Emerging digital practices supporting student-centered learning environments in higher education: A review of literature and lessons learned from the COVID-19 pandemic. *In Education and Information Technologies*, 29(2), pp. 1673-1696.

Overby, K., 2011. *Student-centered learning*. Essai, 9(1), art. 32.

Pandey, A., 2023. E-Learning and Education 4.0: Revolution in Education of 21st Century. *In International Conference on Digital Technologies and Applications*, pp. 431-438.

Pasterk, S., Pagitz, L., Weiß, A. and Bollin, A., 2021. DigiFit4All–Conceptualisation of a Platform to Generate Personalised Open Online Courses (POOCs). *In Open Conference on Computers in Education*, pp. 247-258.

Walkington, C. and Bernacki, M., 2014. Motivating students by 'personalizing' learning around individual interests: a consideration of theory, design and implementation issues. *In Advances in motivation and achievement*, v. 18, pp. 139-176.

Wiley, D. A., 2002. *The instructional use of learning objects* (Vol. 1). Bloomington: Agency for instructional technology.

Wolf, M., 2010. Innovate to education: System [re]design for personalized learning. A report from the 2010 symposium. *In Software and Information Industry Association Washington DC*.

Wright, G. B., 2011. Student-centered learning in higher education. *In International journal of teaching and learning in higher education*, 23(1), pp 92-97.