Innovating Blended Learning Model for Professional Education in Manufacturing

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Abstract. Advancements in technology and the increasing prevalence of digitalization in industry require a new approach to professional education. The primary objective is to enhance the skills of working professionals, ensure content is relevant to industry needs, increase learner engagement, and optimize learner and instructor efficiency. To achieve these goals, a new methodology is proposed, utilizing constructive alignment, outcome-based education, and blended learning strategies. This approach incorporates asynchronous digital learning, synchronous online lectures, and interactive debriefing sessions, providing an engaging blend of self-paced learning and active, instructor-led experiences. Evaluation results show an improved course structure and a positive learning experience, despite initial implementation challenges. While not exclusively designed for sustainable manufacturing education, this approach offers innovative learning pathways and has the flexibility to integrate specific modules, such as those related to sustainability. Based on evaluation feedback and measurable learner outcomes, ongoing refinements to this model suggest a promising shift in the approach to professional education within the manufacturing sector.

Keywords: Blended Learning · Professional Education · Manufacturing · Sustainability

1 Introduction

Professional education is critical in the manufacturing sector, a field characterized by continuous innovation and the integration of new technologies. These advances are driving significant changes in manufacturing practices, requiring a workforce skilled in the use of these new tools and methods [1]. Skills play a significant role in the economic growth of a society, on the innovation process, as well as on social inclusion. The global manufacturing industry currently faces an acute talent gap, due to a lack of adequately trained working professionals. Addressing this gap necessitates a deeper understanding

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of how technological advancements in manufacturing are generating new job roles, and the subsequent modifications needed in educational and training programs. Navigating the difficulties related to the supply and demand of skills requires a transformation in the educational models within the manufacturing sector [2]. The International Academy for Production Engineering (CIRP) has promoted the concepts of Teaching and Learning Factories (TLFs) to enhance practical, industry-oriented education and foster academia-industry collaboration [3]. However, TLFs face challenges in scalability and resource intensity [3].

Professional education is closely connected to sustainable development and supports its economic pillar through efficient and accessible educational services. As advancements in science and technology facilitate new industrial innovations, blended learning has become a fundamental tool for organizations to promptly adapt and offer relevant and sustainable learning experiences. While this paper acknowledges the importance of incorporating blended learning to advance sustainable development, its primary focus is to provide effective, and easily implementable training modules that can seamlessly integrate sustainable manufacturing concepts and learning content.

The development of professional education in the Swedish manufacturing industry is a reflection of wider trends in technical training. The discussed initiative began in 2006, with a focus on "Professional Education in Metal Cutting," in partnership with major industrial players such as Volvo Group, Scania, Seco Tools, and Siemens. The training program had multiple goals: (i) to increase interest in technical training among younger industry professionals, (ii) to adapt to fast-paced technological changes, (iii) to introduce new concepts, and (iv) to sustain critical machining skills for the Swedish manufacturing industry. The training program was designed to be versatile and not confined to specific job roles, e.g., machine operators, workshop technicians, production engineers. The flexibility in the modules enabled customization of content to suit different participant mixes, with the option to adjust the balance between theoretical learning and discussing real-world case studies. Although drawn from experiences with large Swedish companies, the program's adaptive design implies that it can be potentially applied in comparable industrial settings worldwide.

Due to the Covid-19 pandemic, all in-person training was suspended in 2020, necessitating the training to be converted entirely to an online format. When restrictions eased, certain components of instruction, such as labs or workshops, were reintroduced. Notably, there was no complete return to the traditional in-person model. The rationale behind this is multifold: companies acknowledged the cost savings from reduced travel, while training providers saw distinct advantages to online instruction. For instance, enlisting remote industry experts for guest lectures. The new mandate focused on designing, developing, implementing, and evaluating blended learning pathways for professional education—to guide future instructional delivery while creating a marketplace that integrates both existing and new learning modules into training programs.

2 Methodology

A new methodology is proposed for the development of blended learning pathways in professional education. The methodology has its theoretical basis in outcome-based education [4], constructive alignment [5, 6], while using Bloom's taxonomy [7] to identify the cognitive levels in the intended learning outcomes. Collective learning [8, 9] and activity theory [10, 11] are included in the model because experience has shown that professional training benefits from interaction between the participants, and this is often the most positive feedback from trainees in the course. In addition, the methodology is refined based on the best practices collected from research literature on online learning [12, 13], blended learning [14, 15], flipped classroom methodology [16, 17], lifelong learning [18, 19], and assessment of online courses [20, 21].

The blended learning approach in this concept involves combining asynchronous (self-paced) and synchronous (real-time) activities, as well as mixing independent and interactive learning activities. The design methodology is illustrated in Fig. 1, it starts by identifying the intended learning outcomes based on the subject matter, lifelong learning goals and the requirements of different stakeholders. The intended learning outcomes are divided into three groups, i.e., cognitive levels, using the modified Bloom's taxonomy [22]: (i) Remember and Understand, (ii) Apply and Analyze, (iii) Create and Evaluate. This method adds an additional cognitive level—knowledge construction—which serves as a reminder that the most important learning outcome is students' active learning after their formal education. Students need to take control and responsibility for their own learning. After the learning outcomes are defined in the cognitive categories, appropriate learning activities are designed for each of them.

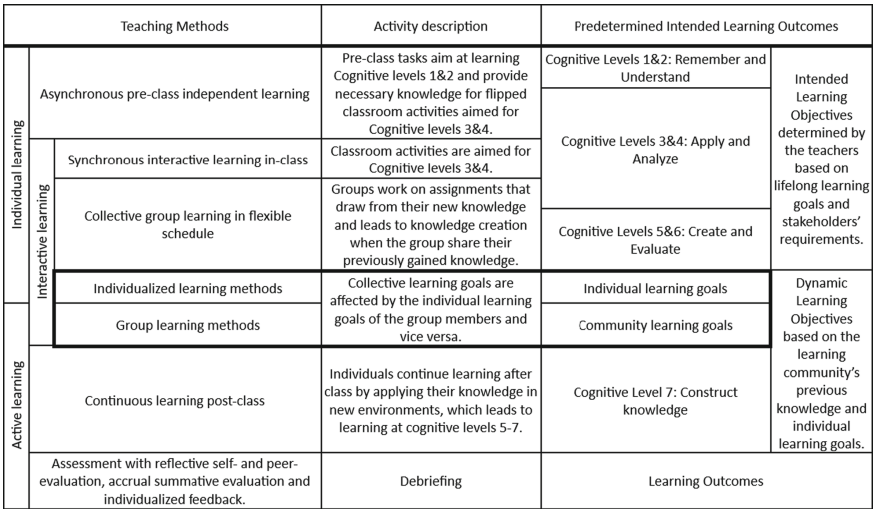

Fig. 1. Design methodology for blended learning in professional education (*collective learning highlighted with thicker borders*).

Asynchronous independent activities are intended for learning the Cognitive Level 1 outcomes, complemented with synchronous flipped classroom activities. Students learn from assigned materials or their own sources before the first synchronous class, depending on their pre-existing knowledge of the topic. The first live synchronous session is designed to activate the knowledge the students have learned prior to class through discussions, group assignments, and exercises. The in-class synchronous activities, targeting Cognitive Levels 1–4, are designed to create initial affinity among students and ease the transition to subsequent group stages.

The group stage includes both asynchronous activities and independent learning, depending on how the groups have agreed to distribute the work, as well as synchronous activities (within a group) to prepare for the final live session, where groups give and receive feedback. The duration of the group stage is intentionally long (9 days) to accommodate the flexible schedules of participants.

The final live session provides a debriefing of the group learning outcomes for the whole class, which helps to align the individual group outcomes in the broader context of the entire learning pathway. Participants in the learning pathway are assessed through self- and peer-evaluation. Independent learning is evaluated using methods such as unproctored online exams, and students receive feedback from the teacher/instructor during the debriefing session.

3 Implementation

The design of the professional courses allows for flexibility to accommodate the primary work commitments of the trainees, offering either four-module (3 ECTS) or six-module (4.5 ECTS) options. Each module is organized over a two-week period (see Fig. 2) and can be illustrated as follows:

- Pre-learning: Before the start of each module, students/trainees engage in pre-learning learning activities, such as viewing short videos or working through digital learning nuggets. These activities are designed to familiarize trainees with the module's topic, adhering to the flipped classroom model, and ensuring they are ready to actively participate in the upcoming live lecture sessions.
- Synchronous instructions: Trainees participate in live online sessions using video conferencing tools, interacting primarily with the instructor(s) in real time. Chat is a supplemental feature that helps trainees ask questions or share comments. These online sessions not only deliver the instructional content, but also facilitate interaction and group discussion among course participants, for example by using breakout rooms for more focused discussions.
- Asynchronous learning period: Trainees are given two weeks to gain a deeper understanding of the subject matter at their own pace. Trainees have access to screencasts recorded during live lectures, readings, and lecture handouts. They also engage in individual or group assignments, using conferencing or digital tools for quizzes.
- Debriefing session: The live debriefing sessions provide an opportunity for trainees to reflect on their learning experience. Instructors provide feedback on learning objectives and assignments, facilitating an open dialogue about the module's subject. While structured, these debriefings are also designed to encourage sharing of experiences in

an informal setting. For example, participants are encouraged to share challenges they have encountered in their respective companies—or to disagree with the instructors.

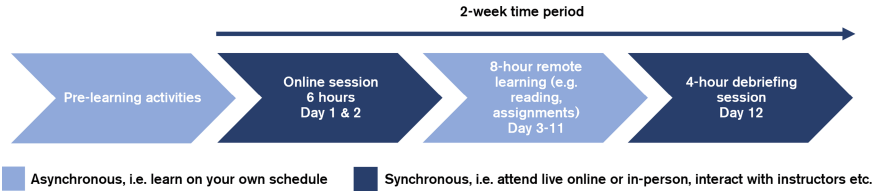

Fig. 2. Learning pathway example for blended professional education.

In the context of the courses discussed, a module refers to a distinct unit of content devoted to a specific topic, similar to a chapter in a book. For example, in a Metal Cutting course, modules such as "Machinability", and "Cutting tools" each house their respective pre-learning activities, lectures, assignments, assessments, and debriefings.

4 Evaluation

Two courses were developed using the proposed methodology. They covered diverse aspects of metal cutting and were conducted in 2021 and 2022 for working professionals in manufacturing industry, ranging from bearing, tooling to automotive sectors. Course 1 consisted of two-week modules, while Course 2 utilized shorter, one-week modules. Each course had 12–15 participants.

Feedback from trainees was collected during each course implementation. First, interviews with randomly selected course representatives were conducted halfway through the course, to provide timely and informal feedback that allowed for potential adjustments to the remainder of the course. Second, an anonymous survey was sent to all participants at the end of the course, to solicit trainees' opinions and perceptions of their learning experience. In the survey, learners were asked to rate their level of agreement with multiple statements using a five-point Likert scale. In addition, open-ended questions were also included in the survey to receive more specific feedback. Some noteworthy comments are summarized in Table 1.

High average scores were observed for all statements in Table 1. The overall impression of the course, the course structure, and the teaching received particularly high scores—indicating a positive perception of the format and delivery of the courses.

More specific comments from the course participants further emphasized the positive perception of the course structure, as reflected in comments 1 and 2 (in Table 2). The two-week asynchronous period between lectures and debriefing was particularly well-received, as it provided sufficient time provided to explore the topics in depth through individual and group assignments (Comment 2). The group assignments also had the positive effect of allowing networking among the trainees in an online format (Comment

Table 1. Average scores of five-level Likert scale course evaluation. The levels are: 1. Strongly disagree, 2. Disagree, 3. Neutral, 4. Agree, 5. Strongly agree. Response rates were 92% (Course 1 2021), 33% (Course 1 2022), and 47% (Course 2 2022).

Statement	Average ratings		
	Course 1 (2021)	Course 1 (2022)	Course 2 (2022)
The course structure is appropriate to reach the intended learning outcomes	4.64	4.75	4.29
The teaching worked well	4.55	4.50	4.43
The assessment (e.g., assignments) tested whether I had reached the intended learning outcomes	4.45	4.75	4.00
The organization and teaching of this course have been designed and executed so that everyone can feel included, welcome and seen/heard	4.64	4.75	4.29
What is your overall impression of the course? (1. Very poor, … 5. Very good)	4.82	4.75	4.57

6). In contrast, the one-week asynchronous period was not well received, as participants found it difficult to fit into their work schedules (Comment 3). Another aspect praised by trainees was the online format of the course (Comments 4–6), in particular its time efficiency.

Despite the largely positive feedback, some common challenges associated with online teaching were identified. These include the issue of passive participants (Comments 7–9), which highlights the importance of incorporating interactive elements, such as interactive discussions or group assignments, in both synchronous and asynchronous sections of the course.

5 Conclusions

The transformation of professional education in the Swedish manufacturing sector was marked by a shift from traditional in-person training to a fully online model. At the core of this change was a course design methodology that incorporated constructive alignment, outcome-based education, and blended learning. Positive feedback was received for the learning experience, but challenges were identified, particularly the creation of resource-intensive digital pre-learning materials. The online format was appreciated for its efficiency, flexibility, and access to recorded lectures. A two-week module structure was preferred for deeper engagement with the topics. Networking was facilitated by group assignments, even in an online environment. However, scheduling issues were

Table 2. List of relevant responses to open-ended questions in course surveys**.**

Comments on course structure	
1	*"I liked the way with modules. And also the assignments, both group and individuals. And that we ended with discussions on Friday."*
2	*"[…] The time between lecture and debrief was perfect to work on the assignments and to dive deeper into the topic, and the debriefings were very good for reviewing the learnings and for discussing open questions." (Course 1)*
3	*"Earlier courses with wider spans felt easier to manage than 6 weeks of stuffing. Managing group assignments in a couple of days was more of a stress than an aid in this, even though the discussions were meaningful." (Course 2)*
Comments on online-format	
4	*"For me the structure was just right. Having the course online allowed more time for me to go away and do some self-learning to catch up on areas that i wouldn't have been familiar with before joining the course."*
5	*"[…] I preferred the virtual aspect more than i thought i would and actually think it was better than face to face. I don't think it would have attended if it hadn't been online. […]"*
6	*"Got to know new persons and did not expect that from a remote course. So this was a learning as well that remote can replace physical course. Also time effective, if physical I would probably not have assigned."*
Comments on teaching, learners' active participation, and learner-instructor interaction	
7	*"The teaching was mostly very good. I would only encourage to have more (very short-5 min) discussions between lectures to prompt students to participate and not just listen."*
8	*"This is a challenge, some hesitate much more than others before taking part of the discussions or assignments."*
9	*"It might be a good idea to set "rules" or "expectation" regarding camera use for the students, maybe specify that during set points such as for in-class discussion it is expected to switch on your camera to enable interaction, perhaps after/between different segments where discussion is wanted. I feel this would improve the discussions and make it easier for the lecturers as well."*

reported with one-week modules. The need for more interactive elements to engage passive participants was recognized. To address this, interactive features need to be integrated into both pre-learning content and live-streamed labs, complemented by the use of breakout rooms in live sessions. This highlights the need for further refinement of the blended learning approach presented.

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