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Professional Development Based on Sustainability with Materials Components – Online vs In-Person

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Professional Development Based on Sustainability with Materials Components – *Online vs In-Person*

This paper describes the background and creation of a professional development training course, which uses as its starting point materials, resource use and emissions caused by product components and their lifecycles. Originally, it was five weekly *online* 3-hour sessions under the title *Sustainable Development within Industrial Production*. This online version is compared to a version for *in-person* training, developed for events on location Lunch-to-Lunch, of near identical content. The main session titles of both courses, with strong materials components and engineering focus, were:

- Climate Change and UN Sustainable Development Goals
- Materials and the Environment
- Transport and Environmental Technology
- The Lifecycle Concept within Industrial Production
- Circular Economy and Course Wrap-Up

The results from six completed online courses with, in total around 120 participants, and four in-person events with, in total, more than 60 participants are reported. Both modes of teaching show great progress in terms of the self-assessed prior and final knowledge levels in (i) Sustainable Development (socially, economically, ecologically); (ii) Environmental Issues (pollution, climate, energy); and a moderate increase even in (iii) Industrial Production knowledge (engineering, economics, logistics). Since the company in question is active in industrial production, the participants were expected to be quite knowledgeable in this area already. The content was clearly materials-based due to its context, despite these classifications.

When the coronavirus pandemic hit, 2020-2022, it forced many Universities world-wide to reduce or modify their teaching almost overnight. It brought forward a transition towards online and remote education that had slowly been gaining ground since the development of internet. In the case of professional development, training courses *in-person* can benefit bonding and team building, but remote working conditions and globalization now makes this form of interaction increasingly difficult. Online educational solutions with real-time zoom-type sessions are a sort of compromise, one step closer to live interaction than, say, fully automated digital or AI-based individual training packages. In this study, we try to use experiences and self-assessment surveys to learn more about the pros and cons of an *online* training course and compare it with an *in-person* version of very similar content. The results indicate that the self-assessed increase in course-related knowledge, at least in the short term, is even better in-person than online.

Materials Background

Everything solid around us is made of materials. With the exception of a few renewable or natural materials, most engineering materials are produced from limited resources with substantial associated environmental impact. In this article, we describe the background and creation of an original online training course, which uses as its starting point the resources used and emissions caused by component materials of industrial products, and their lifecycles. This is a macroscopic approach, very different from the phase diagrams and microstructures of a regular materials science course. Nevertheless, it describes how materials and related energy use can be essential parts in the teaching of Sustainable Development, with elements taken from previous Materials Science & Engineering courses that ran for 10 weeks at half of full-time pace.

University West is located in Trollhättan, Sweden, which has proud traditions of industrial production, such as automobiles (SAAB), locomotives (NOHAB), and currently mobility control (Parker Hannifin), energy (Siemens) and aerospace (GKN), all prominent technology areas involving advanced materials. This town has also made itself known for forward-thinking activities within domestic infrastructure, such as biogas city buses [1], extensive renewable district heating [2] and production technology [3], as well as higher education. It is a medium-sized Swedish town with links to this industrial history that makes it a main local provider of graduated Engineering students. That was also one reason for the *online professional development* course program that was created by this University as an Industry-Academy collaboration, within the ExSus project (*EXpert Competence for SUStainable Production*).

Since the Aerospace and Transport industry are some of the main local stakeholders, it was natural to include a strong focus on relevant, so called, *critical materials*, like high-temperature superalloys, high performance magnets for electric motors and Lithium-Ion based battery materials for electric vehicles. A participant of one of the original online courses, *Introduction to Sustainable Development within Industrial Production*, initiated a discussion with the Sustainability Manager of his regular employer, the VBG-Group, with headquarters in Vänersborg, near University West. This led to the procurement and development of a series of dedicated *online* and *in-person* courses for this company, which are described and compared in this article.

Over the past several years, VBG Group has systematically led sustainability efforts in Sweden and globally, focusing on integrating sustainable practices across the organization. That has guided the company towards aligning with international sustainability standards, such as *Global Compact* and a commitment to the *Paris agreement* as well as support for United Nations *Sustainable Development Goals (SDGs)*. Sustainability has become an overall target of VBG Group, on par with economic profitability and growth. This approach has positioned this company as forward-thinking within their manufacturing sector, which in their case include, *e.g.*, trailer couplings, climate control and snow chains. Since their production is relying heavily on many types of industrial materials, this course was considered suitable for key staff members.

The description of the original course content was (aerospace industry was later de-emphasized):

- This course deals with some of the sustainability challenges we have within transport, automotive and aerospace industry, as well as different concepts towards understanding and solving them.
- The course is remote (not flexible) with online sessions. Each week, one theme is treated, including online lectures, literature and video clips, group activities and an assignment with feedback.

In addition to one preceding welcome session, with participant introductions, web platform and content presentation, **five session themes** were designed, in order to reach the course goals:

1. Climate Change and UN Sustainable Development Goals
2. Materials and the Environment
3. Environmental Technology and Transport
4. The Lifecycle Concept within Industrial Production
5. Circular Economy, Presentations and Course Wrap-Up

The contents following **session 1**, which was a necessary starting point to justify the course, all had significant materials components. Even the sustainable development goals, particularly goal 9 "Industry, Innovation and Infrastructure" and goal 12 "Responsible consumption and production" have strong links to materials. **Session 2** introduced the periodic table, material classes and basic materials properties, for example steel, including steel production. **Session 3** described materials used, *e.g.,* in electric vehicles, such as Lithium and Cobalt in electrodes or those in fuel cells, as well as rare earth magnets. **Session 4** dealt with material resources and material flows in product lifecycles and, finally, **Session 5** extended lifecycle thinking to consecutive product lives, including waste, recycling and reuse themes.

Methodology 1 - Guiding principles in the online professional development

The specific VBG Group course was developed based on previous experiences from the original advanced level (post bachelor) online course at University West, March 2022, mentioned in the previous section; *Introduction to Sustainable Development within Industrial Production*. The intended participants were originally professionally active employees of manufacturing industry with relevant educational background or equivalent experience, but it was also offered externally, free of charge (as normal in Sweden) to applicants with adequate qualifications. The extent of this prequel was 2.5 credits (2.5 hp) which corresponds to a minimum of 65 hours study work, whereof around one third was lectures and supervision. The rest is expected to be individual work, 5 weekly assignments, or preparations. The original scope was: "A collaborative project in sustainable and digitized production regarding ecological, social and economic aspects that aims to strengthen the companies' competences for a more competitive and sustainable future". The examination consisted of passing the 5 assignments given with a pass grade on each. The original course name and the format, introduction plus five 3-hour online sessions, were kept in the VBG Group course series described here, that started September 2022.

The assignment for the first session, normally due one week after the introduction, was revealed in advance and posted online. A *flipped classroom* approach means that participants receive texts, video links and other material via the learning platform (Canvas in our case) to prepare and submit the assignment ahead of the subsequent session theme. The quality control and examination were managed by scrutinizing answers to assignment questions and require at least 80% correct. Failure to reach this minimum resulted in correction requirement. The flipped classroom model is highly adaptable for online courses, providing several benefits that align well with the needs of remote learners, especially in professional development settings. It works particularly effective in online courses on sustainability, for several key reasons:

In a flipped classroom model, learners are introduced to most course material (*e.g.*, texts, videos) ahead of the class session, reserving in-class time for clarifications, discussions, and more interactive reflections. This approach promotes *active learning and engagement* [4], since participants can apply their own real-world examples and discuss during class. It aligns well with the practical nature of sustainability, where professionals benefit from engaging in examples and discussions that promote critical thinking.

Perhaps the most important practical reason is that these professionals come from diverse backgrounds with varying levels of expertise. A flipped classroom allows participants to *learn at their own pace* [5] before coming to class, ensuring that they grasp fundamental concepts. This flexibility accommodates different learning styles and levels of prior knowledge, creating a more inclusive learning environment. It encourages a habit of *self-directed and lifelong learning* [6] among professionals, which is essential for staying updated on emerging sustainability trends, technologies, and policies [6]. Online flipped classrooms naturally support self-paced, self-directed learning to some degree, which is a core benefit of this model. Learners in professional development courses on sustainability can revisit recorded lectures or supplementary materials as needed, ensuring that they have a solid foundation before participating in interactive sessions.

Flipped classroom teaching thus adapts well to online professional development courses on sustainability. It offers flexibility, engagement, and critical thinking, and promotes lifelong learning, while utilizing the benefits of digital tools and virtual learning environments. All of which are essential for professionals to effectively address complex sustainability challenges.

Methodology 2 - *in-person* version of the professional development

An interesting development was the opportunity to attempt to deliver the same course content to employees of VBG Group *in-person*, where that was possible and suitable. The pilot *Lunch-to-Lunch* version was given in Gothenburg to Scandinavian staff November. 2023. The session themes and introduction were kept as similar as possible to the online version. This was part of the intention from VBG Group, in order to harmonize the knowledge levels and benefits from this company-wide and global educational effort. The outcome is, of course, affected by the difference in timescale; 6 weeks *vs* 2 days, which is what we would like to study in this paper, but practical considerations and geographical aspects demanded this organization. The mixture of participants was comparable in the two models, a variety of sales, purchase, directors, administrative staff from several of VBG Group's product areas and regions were represented, many with very considerable work experience.

Results - Learning outcomes

At the introductory online sessions, preceding the first theme, an interactive word cloud survey was conducted to gauge the expectations on the content. The question that was asked was: *What words do you think of when you hear sustainability within industry* (bearing in mind that the participants were mostly experienced in their roles as employees of VBG Group). A typical answer from one of the first online groups is shown in Figure. 1 [7]. It indicates that the conceptual expectations are quite realistic, and materials, waste or circularity are prominent themes.

Figure 1. One typical result from a word cloud question to participants at the introductory online session: What words do you think of when you hear sustainability within industry

In alignment with the Bologna process [8], *outcome-based* examination criteria were adopted and published before the start of the course. The learning outcomes (see below) were defined in close agreement with the 5 session themes mentioned above:

After completing the course, the participants should be able to:

1. Demonstrate knowledge about the causes of climate change and the UN's sustainable development goals.
2. Describe basic relationships between material production and environmental impact.
3. Give examples of and account for energy aspects of environmental technology and transport.
4. Demonstrate a general understanding of the lifecycle concept related to industrial production.
5. Show the ability to apply the circular economy concept to applications in industrial production.

These are intentionally designed to start with sustainability problems or challenges and progress via a combination of two relevant themes for this group, materials, and transport. Towards the end, lifecycle thinking is introduced as a transition into system thinking and the final session is centered around circularity and circular economy, something that is important to nearly all participants, regardless of workplace, division, or role in the company. The examination of this final outcome was a simple PowerPoint presentation to the group (if online, via zoom), individually or in small teams, but relevant to their own workplace. 1-2 hours in total were set aside for this. The topic should cover circularity and sustainability, since this was the theme of the last session and the end of the course. The PowerPoint slides were uploaded as the final assignment, all examined upon their presentations, since there was no next session.

All other, preceding online learning outcomes, were examined by short assignment questions relating to selected texts, book chapters or YouTube video links, providing theory and complementary content to the subsequent online lecture. Discussions between participants offline was allowed, but each person was fully responsible for their individual answers. Around 10 questions were given for each session and, generally, around 80-90% was answered correctly. The limit for pass was 80%, but for minor mistakes, a re-submission was allowed. Small comments and clarifications were delivered as annotations to the documents uploaded via the learning platform (Canvas) and marked in connection with the session. Notable general misconceptions were commented on at the lecture of this topic or naturally clarified via its regular content. Typical examples of questions from session 2 were:

Question 1. (From a video on Industrial Ecology).

- How is Industrial Ecology defined? (multiple answers are possible).
- Materials are not explicitly included in any of the 17 SDGs, even though all things are made of materials. Which goal do you think indirectly most concerns material use and how, justify briefly.

Question 2. (From Michael F. Ashby, Materials and Sustainable Development, Chapter 1)

- Tables 1.1 and 1.2 in the textbook chapter describe an explosive development of materials over the last 100 years. What environmental consequences do you think these trends have?
- Which two metals have by far the largest world production?
- What does *critical materials* mean and why do you think the EU and the US have slightly different lists for this?
- The chapter shows "lists of ingredients" of elements for some industrially manufactured products. What do you think is behind the increasing complexity of the materials?

Although the in-person sessions covered the same topics, the learning outcomes had to be verified in a different way. An individual quiz was used, with typical multiple-choice questions shown in the example from session 2 below:

How many elements are there in the periodic table?

[A] Only around 50
[B] A little over 100
[C] Thousands

How many of the above-mentioned elements are metals?

[A] Only around 20:
[B] Nearly half of them
[C] Considerably more than half of them

Why do copper mines produce more waste than 100 years ago?

[A] Copper has become scarcer and pricier
[B] Mining companies are less environmentally minded today
[C] Copper recycling has become less efficient

What is embodied energy?

[A] The energy it takes to produce 1 kg of material
[B] The energy you can get if you burn the material
[C] The energy you can get back if you recycle the material

Is embodied energy related to a materials carbon footprint?

[A] No, they are completely independent
[B] Yes, but only for metals, such as steel and Aluminium
[C] Yes, the carbon footprint of a material is usually proportional

Which type of polymer can be recycled by remelting?

[A] Thermosets, like Bakelite
[B] Thermoplastics, like PET
[C] Elastomers, like tire rubber

Naturally, these two types of examinations are not equivalent, but they both serve to probe the required learning outcomes, which represent the main goals of the professional development. A course compendium was produced that summarizes each session theme and provided links to relevant material, such as the short videos used. For the in-person training, this was distributed in advance but was followed during the course. For the online version, the material was shared progressively during the weekly sessions and distributed comprehensively as a summary at the end of the course.

Results - Participant self-assessments

The participants were surveyed on self-assessed *pre-course* and *post-course* knowledge levels on relevant topics covered by the courses. Since the learning outcomes were identical, it was possible to compare these results. The general picture was very consistent throughout each course type. Here, the results from the final course, set in at VBG Group's office in York, Pennsylvania with participants mainly from North America (Canada, USA) is taken to represent the in-person training course. The survey results are given in Tables 1-2 below. The values represent the total number of each response. 23 people completed this typical example of one training course survey. The results show clear progress in the self-assessed knowledge, which was the same trend after all 4 in-person training courses.

Table 1, Self-assessed knowledge levels before the in-person training course (number replying)

The purpose of this quiz is to find out your prior knowledge and interests. Your answers will not affect any assessment or examination. We are grateful for your answers.	Don't know	Almost none (1 out of 4)	Some (2 out of 4)	Quite a bit (3 out of 4)	Expert (4 out of 4)	**Average (out of 4)**
1. How would you estimate your prior knowledge of the field of sustainable development (socially, economically, ecologically)?		4	15	4	0	**2**
2. How would you estimate your prior knowledge about environmental issues (pollution, climate, energy)?		1	17	5	0	**2.17**
3. How would you estimate your prior knowledge in industrial production (engineering, economics, logistics)?	1	1	10	11	0	**2.45**

This shows that the North American session in-person consists of participants that consider themselves to have *some* (2 out of 4) previous knowledge of Sustainable Development, but slightly more on environmental issues and between *some* and *quite a bit* prior knowledge about industrial production, which is not surprising for this group. The self-assessed improvement after the training course (marked by Δ) is considerable, with significant increases in all these three categories which is, at least, an indication of successful activities. This is further supported by the following 4 questions, which come closer to *very good* (4 out of 4) regarding content, language and instructor competence. Question 5 confirms that the non-native English was ok.

Table 2, Self-assessed knowledge levels directly after the in-person training course

The purpose of this survey is to find out your acquired knowledge and satisfaction. Your answers will not affect any assessment or examination and will be handed anonymously. We are grateful for your answers.	Don't know	Bad (1 out of 4)	Ok (2 out of 4)	Pretty good (3 out of 4)	Very good (4 out of 4)	**Average (out of 4)**
1. How would you estimate your current knowledge of the field of sustainable development (socially, economically, ecologically)?		0	1	18	4	**3.13** ***Δ=1.13***
2. How would you estimate your current knowledge about environmental issues (pollution, climate, energy)?		0	1	20	2	**3.04** ***Δ=0.87***
3. How would you estimate your current knowledge in industrial production (engineering, economics, logistics)?		0	2	17	2	**3.0** ***Δ=0.55***
4. How good do you think the content of the course has been?		1	2	6	14	**3.43**
5. How do you think we managed the language in the course (English)?		0	1	4	18	**3.74**
6. How good did you find the instructor of the course (Claes)?		0	2	6	15	**3.57**
7. How well do you think this course will contribute to the sustainability work within VBG Group?	1	0	1	8	13	**3.55**

For the online training, the same questions were implemented in the canvas platform and also surveyed early at the introduction session and after course completion, respectively. All 6 courses show similar results. The example shown below is from one of the last online courses in 2023. Note that only 13 participants had joined at the time of the introductory survey due to delays. Judging by the other introductory online surveys, this does not affect the main conclusions. The results are given graphically directly from the Canvas system, shown in Figures 2-4, and concerns (i) Sustainable Development, (ii) Environmental Issues and (iii) Industrial Production. Figure 5 is included to demonstrate the consistency and quality of the responses.

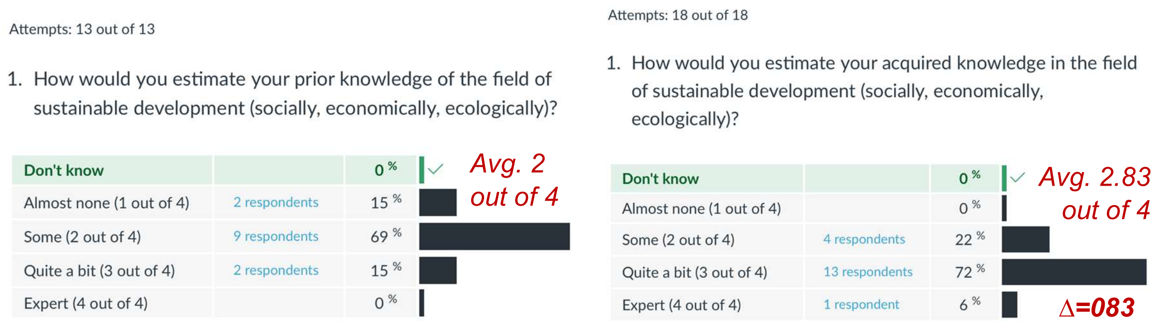

Figure 2. Self-assessed knowledge levels (i) before and after the online training course

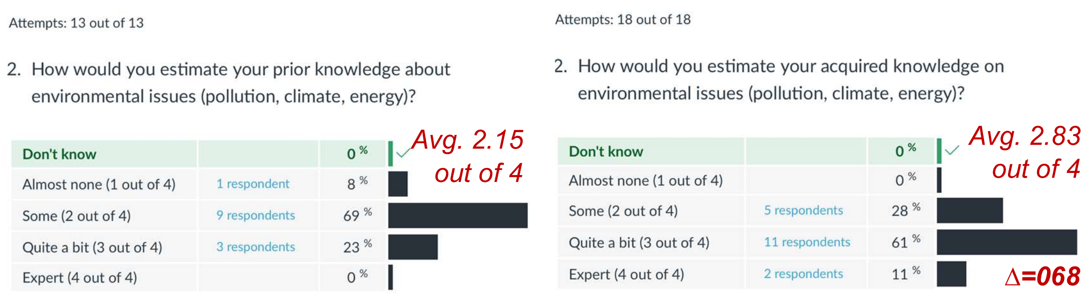

Figure 3. Self-assessed knowledge levels (ii) before and after the online training course

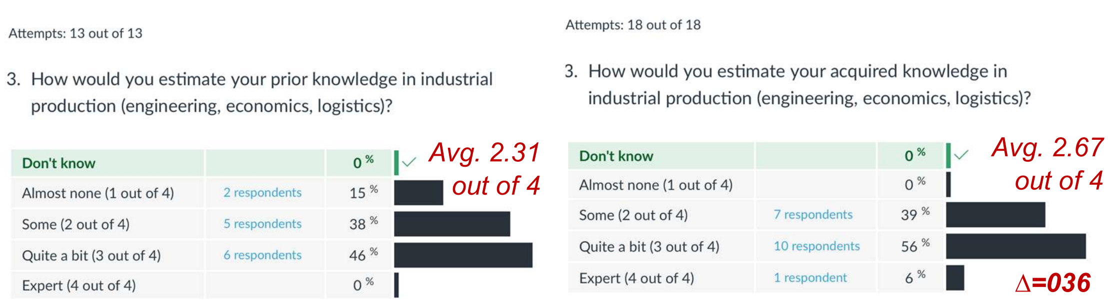

Figure 4. Self-assessed knowledge levels (iii) before and after the online training course

So far, the results indicate that the pre-course knowledge levels are comparable but that the self-assessed improvement is significantly higher *in-person* (Δ=1.13, 0.87 and 0.55) than in the online course shown in these Figures (Δ=0.83, 0.68 and 0.36), which are still quite good. The validity of this observation is supported by very high appreciation of content and instructor quality (Avg.=3.72 and 3.94 out of 4), meaning that it does not reflect unhappiness in any way.

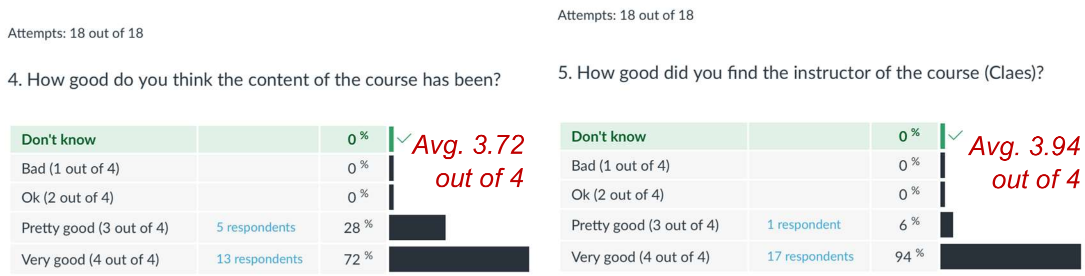

Figure 5. Indicators of the perceived quality of the online training course

Summary and Conclusions

We have described the background to the development of a professional development course on sustainability based on components relating to materials. The *online* flipped-classroom approach has been compared with an *in-person* version consisting of the same 5 session themes.

The multiple-choice scales in all cases used ranged from 1 out of 4 (almost none/bad) to 4 out of 4 (expert/very good). We conclude that there has been significant self-assessed knowledge increase in all surveyed aspects for both models; Sustainable Development, Environmental Issues and Industrial Production, and conclude that our materials-based approach is effective.

Furthermore, although these self-assessed knowledge improvements are considerable for the *online* training model (Δ=0.83, 0.68 and 0.36), they are significantly higher for the *in-person* Lunch-to-Lunch training model (Δ=1.13, 0.87 and 0.55). This trend is consistent also in the other events carried out under similar conditions but with other groups within the company.

High evaluations after the last sessions of the courses of content and instructor quality (3.43-3.57 out of 4, in-person *vs* 3.74-3.94 out of 4, online) indicates that the higher self-assessed knowledge improvement for *in-person* training is not an artifact of unhappiness online or "better" instructor performance *in-person*.

It has not been possible to follow-up differences in retention of these two models, due to practical circumstances of professional development within VBG Group, but hope that the result from the question in-person: *7. How well do you think this course will contribute to the sustainability work within VBG Group?* is closer to *very good* than *pretty good*, as in the survey.

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