Introduction

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The last time you went to the bakery, did you wonder how the baker had been trained? Did he follow theoretical courses or only practical ones? What about your car mechanic? Do you know how long her training was or whether it was generic or specific to a car brand? How long did her training take and was she being paid during this time?

Similar to most people, you may not be able to fully answer these questions. As a matter of fact, these answers vary country by country, often according to profession. In Switzerland, where vocational education and training (VET) plays a central role in the educational landscape, citizens might be able to provide some answers. They would tell you that VET is applicable to two-thirds of Swiss teenagers, that it is taught during the upper secondary school (± 16-20 years old) and that it covers many professions (salespersons, carpenters, hairdressers, office clerks). Indeed, over 240 professions come under VET training. They might also explain that the Swiss VET system is described as 'dual' because most apprentices alternate one or two days per week at school with working in a company as employees and receiving a salary.

These are easy questions, but for many years, higher-level questions have remained unaddressed by local universities. Is the Swiss VET system actually effective? Do host company trainers provide high-quality follow-up for their apprentices? Is school content relevant to the workplace? Do apprentices constitute a cost or a benefit for companies? Are there dropouts and what are the causes for them dropping out? For decades, Swiss universities have seen many scholars investigating other sectors of education, from kindergarten to lifelong learning, but only a few universities researched VET. Realising this weakness at the beginning of this century, the State Secretariat for Education, Research and Innovation (SERI), that is, the federal office in charge of VET, invited various consortia to apply for funds to do research according to several themes. One of these themes was about the development of digital technologies in VET contexts, and we obtained this research grant as a partnership between four institutions (see acknowledgements section).

This book summarises 15 years of research (2007-2021) on the exploitation of digital technologies for VET. In other words, our activities started the same year as the first iPhone was launched! Four research groups formed the leading house on the topic, named DUAL-T, where T stands for technologies and DUAL refers to the Swiss VET system, relying to a great extent upon the alternating of days at school and days in the workplace. This uniquely long-term research scheme has gathered more than 50 research scientists, produced 13 doctoral theses, led to the development of multiple digital learning environments and enabled dozens of empirical studies on thousands of apprentices and hundreds of teachers and company trainers. DUAL-T developed a network of stakeholders, including vocational schools and companies, but also many professional organisations and cantonal or national public entities. This book does not provide a detailed account of all these activities, which have been published elsewhere. But it proposes several answers to the question:

"***Which digital technologies contribute to the enhancement of vocational education?***"

In VET systems, as well as in other education sectors, the choice of educational platforms is not made by teachers but is often a decision taken at the school, the district or a higher hierarchical level. Therefore, along our 15 years of negotiations with schools, many teachers declined to use one of our tools because they were constrained by these top-down decisions. In this book, we aimed to make design choices as independent as they could possibly be from school platforms. Some constraints could not be avoided, but some ideas that used our tools could be implemented with WhatsApp, Instagram, MS Teams and Google Drive.

Target audience

The VET systems around the world are different from the Swiss VET system, with the exception of Austria and Germany, and, partly so, the Netherlands. However, we paid special attention to describing our work in a way that would be meaningful beyond Swiss borders. We wrote this book because we believe that many of the issues we tackled are relevant for any VET system worldwide, such as the differences between knowledge taught at school and knowledge required by the profession. Moreover, we think that many of the solutions we tested and more generally the pedagogical approach we developed could be useful even beyond VET, that is, wherever formal and informal learning occasions happen, which happens almost everywhere in one's professional life.
We also wrote this book as an invitation to the international community in the learning sciences and in educational technologies to pay more attention to the VET system in their own country, even if it is differently structured. As many researchers in university labs have not gone through a VET path, the VET context is clearly under-sampled in academic publications. We would even add that several of the issues we address are relevant beyond VET: tangible manipulations, augmented reality or learning analytics are affordances that enhance any sector of education. Therefore, we expect this book to generate ideas for many education scientists, whatever domains and countries are involved in their studies.

Potential effects

What are the effects of massive open online courses (MOOC) on education? That is the kind of wicked question we have been often asked in recent years. The only rigorous answer should be 'none', or, to be more verbose, it could be that good MOOCs are better than bad MOOCs. This 'Lapalissade' applies to any variation of this question that you obtain by replacing MOOCs with other terms, such as augmented reality, artificial intelligence and robotics. The history of learning technologies is paved with over-generalisations and their corollary, over-expectations. They result from a mix of enthusiasm and naivety, or commercial interests. Over-expectations are actually detrimental to education, since they inevitably lead to disappointment.
We conducted many empirical studies with the digital environments we describe in this book, some with disappointing results, some revealing statistically significant increases in learning gains. However, even in the successful cases, we carefully do not conclude that technology X has effect Y, for instance, that tangible interfaces increase learning outcomes. Over-generalisations generate over-expectations. An experiment with successful outcomes does not guarantee that any tool using the same technology will produce the same results. **These experiments demonstrate a potential effect, not a guaranteed effect**. As an example, even if a study showed that some augmented reality (AR) environment increased learning gains, one cannot extrapolate that any AR would have the same effectiveness in any context. It would, of course, be easy to design another AR in which learners fail to acquire any knowledge. Does this mean that we cannot conclude anything from a successful experiment? Of course not! What is important to stress here is that technology has no direct, automatic effect on learning, as the relationship between technology choices and learning outcomes is a multi-step one. This relationship comprises four steps: (1) when incorporated into the training appropriately (from an instructional design point of view) by teachers and trainers, the technology enables learners to (2) engage in specific individual or team activities (e.g. problem solving, reading, arguing, explaining) and these activities (3) trigger cognitive processes that (4) occur to influence the learners' skills or knowledge. For instance, one may obtain great results (4) with an AR system (1) for gardeners and poor results (4) with another AR system on the same skills because the activities (2) that apprentices do in the latter do not trigger the required cognitive processes as they did in the former example. The goal of this book is to reveal this causal chain. The following chapters disentangle the design features of a technology (1) that enables rich VET activities (2) that are in turn hypothesised to trigger cognitive processes (3) that support learning (4). We will even see that there is a fifth factor in the equation: the way the teacher orchestrates these activities in the classroom.

Research questions and structure of this book

We first provide the reader with background information about the Swiss VET system. **Chapter 1** is not a comprehensive overview of this system but provides the contextual elements necessary not only to understand our research activities, but also to disentangle from the contributions of this book the ones which can be exported to different VET or non-VET systems.

We now present an outline of the other chapters in chronological order.

We started with a simple question: ***can VET use the same learning technologies as other upper secondary schools?*** The answer is rather positive for learning technologies that do not include any initial content, such as learning management systems, classroom participation systems or collaboration tools, the contents being added by teachers and learners. Many VET institutions use the same generic tools as other schools: Moodle, Zoom, Google Drive, clickers, for example. The answer to the main question is different for tools that embed specific content, such as online courses or science simulations. In fact, VET curricula include a subset of what is taught in high schools in mathematics, languages and citizenship, among other topics, under the umbrella of 'general culture' - also known as 'Language, Culture and Society (LCS)'. However, this knowledge is often addressed by VET teachers in more concrete, less academic ways than in general secondary schools, as the latter prepares students for universities. For instance, a chemistry simulation or a MOOC on mathematical functions that are useful for general high school may be too theoretical for VET students. The true spirit of our overarching research question does not concern so much the reuse of generic learning tools used in high schools as the exploring of technologies that are different from general technologies, that is, that would be specifically relevant to VET contexts. To reflect this bias, our question can be rephrased as: **would a VET system benefit from specific learning technologies, designed purposely for addressing VET needs?**

Even if the presentation we give of the VET system does not cover its full complexity, the reader will immediately understand what German colleagues call the 'two places problem', that is, the misalignment between the two legs of the dual system, the school and the workplace. By talking to teachers, apprentices and company trainers, we quickly realised that 'skills gaps' exist between these two places: what apprentices learn at school is not necessarily perceived by apprentices as useful for their workplace activities and what they do in the workplace does not allow them to give meaning to what is taught at school. These two places differ according to the type of knowledge and skills they provide but also according to their objectives. While workplace managers expect reasonable short-term productivity, schools have a longer-term vision. For instance, when assigning tasks to logistics assistants, warehouse managers do not expect them to reorganise a warehouse – the role of the manager – but simply to operate efficiently based on the instructions given by their in-company trainers. On the other hand, schools teach how storage areas can be optimised, a skill apprentices might benefit from maybe 10 years into their profession once they, in turn, become warehouse managers. In other words, even if skills are impervious to being transferred, that is, reusing in daily work what has been learned at school, they are not a bug in the system, but an intrinsic feature of it: the two institutions, the school and the company, have complementary roles, sometimes having a long- versus a short-term impact. To phrase it differently, a system would not be dual if learners were to encounter identical experiences at schools and in companies. Therefore, the solution to the 'two places problem' is not to eliminate this skills gap, that is, to erase the differences between the school and workplace learning if this was even feasible. Instead, our approach is to exploit these differences by connecting workplace experience and school activities, **to use technologies to let apprentices make sense of what they have learned in one context within another context**. We refer to this first hypothesis as **building digital bridges** between schools and workplaces. We translate this principle into action by capturing experience in the workplace as a digital substance in order to feed classroom activities and, conversely, to enhance workplace activities with transferable school knowledge. We refer to this vision as **'der Erfahrraum'** and develop it as a theme in **Chapter 2**.

Chapters 3, **4** and **5** illustrate **how this vision has inspired teachers and trainers in five rather different professions**, – bakers and cooks (Chapter 3), painters (Chapter 4), and clothing designers and beauticians (Chapter 5) – and how they have managed to take advantage of the technologies we brought them to improve the alignment of these various learning places – bridging the learning advanced at school in line with experiences learnt in the workplace.

Apprentices have to learn skills that are different from what other teenagers have to acquire in high school. VET curricula include profession-specific courses, such as hair structure for hairdressers or wood typology for carpenters. The diversity of these courses reflects the diversity of the 240 professions in the Swiss VET system. Many learning activities in these curricula share the need to manipulate physical objects or to perform professional actions, which is rarely the case in general high school. VET schools also benefit from digital technologies in which apprentices have the opportunity to manipulate, physically or at least virtually, realistic professional objects. When we started in 2006, the interactions between a learner and a learning environment were limited to a mouse and a keyboard, at least in daily practice. To enrich learning with more physical interactions, we pioneered the development of tangible interfaces, but also AR and even virtual reality systems. Nowadays, with the growth of the Internet of Things and the ubiquity of additive manufacturing, the continuity between digital and physical aspects does not need to be demonstrated anymore to the actors of the VET system. **Chapters 6 through 8** describe **how such technologies have been designed and implemented in VET schools** and we report on the results from empirical studies conducted within four different professions – logisticians (Chapter 6), carpenters (Chapter 7), florists and gardeners (Chapter 8).

The more complex a system is, the more effort is needed to monitor the way it functions. Nowadays, a car or a plane are complex systems that are fully monitored through sensors. Some sensors capture data from their inner components; others capture data from the outside environment. Education systems are also equipped with inner sensors, such as failure rates, and outer sensors, such as those that track the professional development of those who have completed the studies. These sensors are rather slow data collection processes, such as surveys or aggregation of school statistics. Therefore, regulatory cycles are several years long. Our third hypothesis is that faster regulation could be achieved by accelerating the adoption of learning analytics. Learning analytics are methods of following the state of learners at different levels of granularity, from the individual performance in a single exercise to the national drop-out rate in some training fields. By collecting data systematically and rapidly, and by processing these data with machine learning methods, technologies provide teachers and decision-makers with faster information. For instance, some machine learning methods, when fed with sufficiently large datasets, might be able to predict whether an apprentice will drop out or not. Several projects within DUAL-T have explored the specific benefits of **learning analytics** for the VET system, as described in **Chapter 9**.

Various technologies rather than a specific technology

This book is not about a specific digital technology. The many meetings we had with apprentices, teachers and in-company trainers, as well as our commitment to work from and around their educational needs, as inferred from these discussions, led us to consider various technological choices and possible solutions.

Our point is that the relevance of other technologies, such as online courses, drill & practice courseware, simulations and intelligent tutoring systems, should not be minimised. Our technological choices result from our quest for VET-specific technologies. One drawback of this approach is that many of the tools we developed are specific to one or a few professions: for instance, our AR tool for an intuitive understanding of statics was designed for carpenters; it is relevant to other construction trades (bricklayers, metallic construction, cabinet makers) but not to salespersons, nurses' assistants or chefs. The didactical ideas behind these specific tools, however, may well be suitable for many more professions. The framework created specifically

to teach security and environment protection to painters can easily be transported, *mutatis mutandis*, to the many professions concerned with these issues, such as electricians, chemistry labs assistants, electroplaters, crosscut saw operators and body builders, to name just a few.

What this book does not address

Over the last six years, before the pandemic was heard of, we witnessed a rapid evolution in the attitude of education stakeholders towards the digital transformation of the VET system. The main reason of this evolution is unfortunately not the work that is reported in this book but the digital transformation of professions themselves: the fourth industrial revolution is impacting almost all professions: additive manufacturing, the Internet of Things, systems analytics, on-demand production, online markets. Nowadays, a car mechanic still requires the skills to assemble mechanical pieces, but also needs an understanding of the sensors and digital diagnosis tools that equip all cars. The Swiss VET system is designed to rapidly adapt to the evolution of trades; monitoring those changes is part of its DNA. Few education stakeholders actually distinguish this transformation of trades from the evolution of learning technologies, a confusion that actually helped us get the attention of many stakeholders. However, this book does not address the first topic, only the second. The analysis of job evolution belongs to other fields, distinct from ours, namely economics and sociology, even though we touched on it when applying machine learning methods for predicting the emergence of new training needs (see Chapter 9). Even if they are distinct, these two facets strengthen each other by raising awareness about how VET institutions should accelerate their adaptation to the digital revolution.

The word revolution, used in the previous paragraph, is indeed relevant if we talk about the fast transformation of jobs, but it does apply to the transformation of schools too. Journalists often ask us to predict the next big revolution in education. 'Are you going to replace teachers with robots?' is not an uncommon (but a stupid) question. 'How will education look like in 2050?' is another common question, which cannot be replied to in any serious way. Yes, there are deep irreversible changes in the education system. Think about Wikipedia or that an apprentice can find several videos on YouTube explaining almost any concept or technique. There are meaningful trends, mainly cultural evolutions, but do not expect a deep education revolution in the next few decades. **This book is not about predicting a future**, neither dramatic nor glorious. It is about informing all stakeholders about **what can be done today** with existing technologies. The future is not yet written: it depends on how teachers, company managers and apprentices will translate digital opportunities into learning successes.

Is this book relevant for those involved in **corporate training**? We will let you judge, as the answer is subtle. The obvious difference between vocational education and corporate training is that the first one is about the initial phase of training and the latter ties in with a professional career. Apprentices have to go to the former, employees usually choose to go to the latter. The former lasts three or four years, the latter a couple of days per year. A noticeable difference is the future of trainees. In vocational education, the company makes no promise to hire the apprentice at the end. Some companies even hire apprentices while explicitly knowing they do not intend to hire new employees. On the other hand, corporate training is offered to employees who are expected to remain in the company; several training managers told us of their concerns that a well-trained employee might leave the company.

Despite these differences, corporate training and vocational education face a common challenge: how is the knowledge acquired during learning/training activities actually used in a way that increases the employee's performance or job satisfaction? This is an issue for many apprentices, who complain that school is useless, as well as for employees who, when asked to assess the relevance of a seminar, comment more often on the quality of the coffee than about the relevance of the course content. We have never met a chief learning officer or head of human resources who computed the return on investment in his staff training: for every dollar spent on training,

how many dollars were gained in higher productivity, better sales, reduced waste, increased customer satisfaction, or staff members' satisfaction at work or their retention? How do education and training efforts actually impact professional practices is an issue both in VET and in corporate training, but it receives more attention in VET. Therefore, this book may also inspire those in charge of corporate training.

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