The Contribution of Vocational Education and Training to Innovation – The Case of Switzerland

Study elaborated as part of the report
"Research and Innovation in Switzerland 2020"
Part C, Study 1

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Content

0 Main findings / Executive summary

In Switzerland, Vocational and Professional Education and Training (VPET) makes a significant contribution to innovation. It partly explains why for many years Switzerland's innovation performance is at the top of international innovation rankings.[3] The VPET system consists of Vocational Education and Training (VET) on the upper secondary level and of advanced Professional Education and Training (PET) on the tertiary level[4]. The contribution of VPET is crucial for innovation in Switzerland, although in the past, scientific or public discussions often only highlighted the importance of universities and academic education. The contribution of VPET is often overlooked because VPET is perceived as too narrowly focused or too limited to outdated knowledge and to conventional technologies. Therefore, a common assumption, particularly in the international literature, is that VPET does not make a significant contribution to innovation (cf. Aghion, 2008; Aghion & Howitt, 2006; Krueger & Kumar, 2004a; Krueger & Kumar, 2004b). While that assumption may be valid in some Anglo-Saxon countries, particularly countries that lack a high-quality VPET system, it is not valid for Switzerland.[5] On the contrary, Switzerland's VPET system makes crucial contributions to innovation in companies and strengthens the innovative capacity of the Swiss economy as a whole. Switzerland's VPET system ensures that its workforce has a sound foundation of vocational and professional competences and provides a wide range of options for lifelong learning and upgrading of skills for individuals. This helps to spur innovation and creates favorable conditions for coping with innovation-induced changes in the labor market.

Swiss VET programs on the upper secondary level provide labor market entrants with profound occupation-specific and practical skills while simultaneously imparting a broad spectrum of professional competences, including methodological and social competences. This is done on the basis of legally binding occupational curricula that are regularly updated and geared towards labor market requirements at the forefront of innovation. The breadth of their training makes VET graduates flexible and mobile (across firms and occupations) and increases their ability and willingness to participate in and to drive innovation processes in companies. The Swiss VPET system therefore makes important contributions to various types of innovation in companies. Accordingly, companies that train apprentices are more innovative than non-training companies, and companies with more VPET workers are to a certain point more innovative than comparable companies without or with fewer VPET workers.

Another important contribution to innovation in Switzerland is made by the Universities of Applied Sciences (UASs). Although UASs are formally assigned to the Swiss university sector[6], their students are VET graduates, and in this sense, they are a crucial part of the VPET contribution to innovation. UASs provide an attractive career option for VET graduates and thus contribute to the attractiveness of starting with a VET program after compulsory education and thereby to the quality of applicants for VET programs in the first place. Moreover, UAS graduates play an important role in companies' workforces: their knowledge and competences build an important bridge between the knowledge of VET graduates with more practical occupational competences and experience, on the one hand, and the knowledge of higher education graduates with applied and basic research skills, on the other hand.

However, innovation-related change requires not only comprehensive occupation-specific competences but also more general "soft skills". These include the ability to work in teams, to manage one's own time and work assignments or to communicate with others. Empirical studies have shown that the company as a learning location is particularly suited for the acquisition of such soft skills. Thus, owing to the systematic development of soft skills during Vocational Education and Training, graduates of VET programs are additionally well prepared for innovation. This in turn supports innovation processes in companies in Switzerland.

Furthermore, the multitude of opportunities for upskilling, i.e. to acquire higher-level professional qualifications in the Swiss education system and the diverse options for career advancements that accompany them is one of the strengths of the Swiss system from an innovation perspective. This is because the multitude of education and career opportunities is an important prerequisite for workers to cope with changing and

[3] For example, for nine years in a row, Switzerland is at the top of the "Global Innovation Indexes"-ranking, which is jointly done by the World Intellectual Property Organization (Wipo), the Insead Business School and Cornell University. The analysis covers 129 countries, which together cover 92% of the world's population and 97% of global value added (cf. Thomas Fuster 24.7.2019, NZZ-online (https://www.nzz.ch/wirtschaft/die-schweiz-ist-das-innovativste-land-der-welt-ld.1497937), last download 24.7.2019.

[4] Professional Education and Training (PET) (Höhere Berufsbildung) builds on a VET degree and additional professional experience. It consists of two paths: first, Federal PET Diploma Examinations that are available on a basic and an advanced level (Berufsprüfung und höhere Fachprüfung) and second study programs at PET colleges (Bildungsgänge an höheren Fachschulen). PET in general is competence based and labor market oriented, it focuses on applied learning, on rapid application of novel competences and on a high innovation rhythm.

[5] One of the few studies examining the role of VET on innovation and stating a positive relation is Toner (2010) for Australia.

[6] The Swiss higher education sector (Hochschulsektor), according to the "Federal Act on Funding and Coordination of the Swiss Higher Education Sector" (HedA or Hochschulförderungs- und -koordinationsgesetz, HFKG), consists of a) tier-one universities (cantonal universities (UNI) and Federal Institutes of Technology (FIT)), b) Universities of Applied Sciences (UAS) and c) Universities of Teacher Education (UTE).

naturally unpredictable job requirements. Advanced Professional Education and Training (PET) degrees are an important component of this multitude of opportunities and at the same time make an important contribution to the tertiary education sector in Switzerland. Finally, empirical studies show that individuals who follow mixed educational paths are more likely to become entrepreneurs than individuals with purely vocational or purely academic paths — and entrepreneurship is an essential component of any economy's ability to innovate.

In summary, it can be concluded that the VPET system in Switzerland creates a solid basis for coping with innovation-induced changes and for continually driving further innovation. It does so by providing education and training in occupations with versatile skill bundles and with a wide range of opportunities for upgrading and career advancement that help to drive change.

Empirical studies on the relationship between innovation and skill structures in Swiss companies confirm a positive relationship between innovation and a broad skill mix, including VPET. This applies both to the early innovation phase (when discovering new ideas and research paths) and to incremental, radical or organizational innovations (with effects that vary depending on the sector, the market dynamics and the HRM system used in the companies). In addition, the effects can be found both in small and medium-sized enterprises and in large companies as well as in the traditional and the high-tech manufacturing sectors.

However, to achieve these effects, there are a number of important preconditions that must be met. The following chapter—based on legal foundations, research results and case studies—identifies the characteristics of the Swiss VPET system that are important for innovation and highlights the key challenges that the VPET system currently faces. The analysis takes place on three levels: 1. system, 2. company, and 3. individual. For each level, the chapter sketches some basic features; then, it concentrates on the characteristics of VPET that are essential for innovation in Switzerland.

The analysis at the *systems level* highlights two aspects: first, the role of curriculum-updating mechanisms and second, the role of permeability in the entire education system. Regarding the first aspect, our analysis shows that a systematic, continuous and innovation-oriented updating of curricula is decisive for the innovative contributions of the VPET system. The systematic and continuous updating takes place within the framework of a cyclical reform process. The innovation orientation depends on companies on the innovation frontier participating in the reform process. This guarantees that the innovative technologies and future-oriented skill requirements used in innovative companies (but not yet in use in all companies) will find their way into the reformed curricula. This in turn makes the updated curricula beneficial for future innovation in all companies. Our analyses further show that a decisive prerequisite for this curriculum-updating mechanism is a well-functioning *VET-partnership* (Verbundpartnerschaft). In this VET-partnership, the state and the “Organizations of the World of Work” (OdAs)[7] collaborate to ensure the quality and the future orientedness of VET and PET curricula.

Regarding the second aspect, our analyses show that high permeability within the VPET system and the university system is a decisive factor for the innovation effect. This is because a high degree of permeability (horizontal or vertical) creates the necessary conditions for workers to be able to adapt to the changing skill requirements brought about by innovation, not only in the short run but also over the course of their entire education.

Our analyses at the *company level* show that the broad participation of companies in apprenticeship training and a diverse skill mix within companies are two important aspects for the innovation effects of the VPET system. First, the broad participation of companies in apprenticeship training (whether the companies are innovative or traditional, large or small, in production or in services) creates a strong leverage for the diffusion of innovation know-how (via innovation-oriented curricula), as briefly outlined above and in more detail in Chapter 2.2. An important prerequisite for the broad participation of companies is a favorable cost-benefit ratio of apprenticeship training for the companies. Second, the diverse skill mix (resulting from the diversity of the VPET system) promotes valuable knowledge spillovers across different types of knowledge and thus helps to spur innovation (as demonstrated by the case studies presented in Chapter 3). Such innovation effects are reinforced if the diverse skill mix is complemented by corresponding personnel and organizational measures and by a matching overall corporate innovation strategy. In theory, there is no one best way to create a skill mix that is conducive to innovation. Instead, companies can and must find—depending on their circumstances—the right combination of skill mix, organizational measures and corporate strategies. Empirical evidence shows, however, that in Switzerland, in the skill mix of innovative companies, workers with VPET skills generally constitute an important element.

The analyses on the *individual level* show that for ambitious VET graduates, promising employment and career prospects represent a first essential characteristic that the VPET system

[7] The Organizations of the World of Work (Organisationen der Arbeit, OdAs) basically include sectoral and occupational associations, employers associations and trade unions (for details see chapter 2). They play a central role in, among other things, the design and reform of VPET programs (cf. Chapters 2.2 and 2.4).

has to meet. Another important characteristic is a wide range of educational opportunities for upgrading qualifications at the tertiary level and for lifelong continuing training and education. Both aspects, employment and educational upgrading opportunities, are essential because they shape important decisions made by individuals after compulsory education. After all, it is individuals who decide for or against choosing a VET path after compulsory schooling, and it is individuals who—to a greater or lesser extent—foster or hinder innovation in companies. Therefore, systemic incentives for individuals play an important role. What are the incentives? For a young person who decides to pursue a VET path, the long-term employment opportunities and the consequent occupational mobility and flexibility (in addition to social status) of different educational pathways are decisive. In Switzerland, empirical evidence shows that workers with a VET degree are highly mobile and flexible and that they have good long-term employment opportunities even under changing job requirements (depending on the skills bundle of their occupation). Such high occupational mobility and flexibility is also a prerequisite for individuals' willingness to participate in innovative developments in their companies. Furthermore, the empirical results show that there are manifold possibilities for upgrading qualifications and for lifelong continuing training and education and that these opportunities are systematically and thoroughly utilized in Switzerland. This ensures a further prerequisite for adapting to changing work requirements and, in particular, for a potential upgrading of jobs in the course of technological innovation.

However, there are also central challenges at each of the three levels mentioned, and overcoming these challenges will be a decisive factor for Switzerland's future ability to innovate.

At the *systems level*, one of the challenges is to ensure an appropriate balancing of interests among different types of companies and their different requirements in VET programs. On the one hand, the balancing of interests must meet the requirements of highly innovative companies. On the other hand, it must meet the requirements of companies that are further from the innovation frontier but that nevertheless provide a significant share of training places. A second challenge at the systems level is adequate systemic control and coordination among vocational training institutions and academic training institutions. This is important because the three unique parts of the tertiary level of the Swiss education system, i.e., tertiary-level Professional Education and Training (PET), Universities of Applied Sciences (UASs) and academic universities (UNIs) and Federal Institutes of Technologies (FITs), each uniquely represent an important success factor in the Swiss education and innovation landscape. Blurring the profiles of UASs and PET, for example (as can be observed, for example, in the health sector), or blurring UASs and UNIs (as observed in some cases) jeopardizes the strengths of the Swiss education system. For example, the combination of sound occupational foundations, science-based training and application-oriented research that constitutes the particularity of UASs serves an important bridging function in the innovation system and should not be jeopardized. This should be taken into account in the further developments of each part of the education system, which should be developed not only with a view to addressing internal problems but also with a view to their roles in the overall education system. An increased blurring of profiles does not well serve the education and innovation system in Switzerland; it represents a danger to the overall system that goes far beyond those directly affected. Adequate systemic control and coordination within and between VPET and academic education institutions is therefore essential.

There are also a number of challenges at the *company level*: first, maintaining the broad participation of companies (especially innovative companies) in VET and in the VET-partnership; second, the effective integration and recruitment of new and international companies for the Swiss VPET system; and third, the increasing difficulty in recruiting a sufficient number of suitable apprentices (these difficulties can be traced to demographic developments (a decreasing number of young people due to low birth cohorts)) coupled with a lack of adjustment in the number of school places at competing schools—i.e., baccalaureate-granting high schools (called Gymnasium[8])—despite the decreasing cohorts (cf. Swiss Coordination Office for Education Research, 2018:120 and Chapter 3).

The main challenge at the *individual level* is to maintain the attractiveness of VET programs for highly talented young people, especially due to international trends and the lower international social status of VET. It must be ensured that talented young people do not increasingly move towards academic education despite the very good income prospects, career options and career advancement opportunities to be gained with a VET degree. Such a trend towards academic education weakens the vocational component of the present-day skill mix, which in turn creates undesirable effects for the innovation capabilities of the Swiss system.

[8] General baccalaureate-granting high school, finishing with a Swiss Matura, which grants general admission to all Swiss universities in almost all fields (the exceptions are, for example, medical studies and arts).

1 Introduction

In Switzerland, *Vocational and Professional Education and Training (VPET)* makes a significant contribution to innovation in companies and to the innovative capacity of the economy as a whole. VPET ensures the vocational qualifications necessary for innovation, thus helping to promote innovation and creating important prerequisites for coping with innovation-induced change in the labor market. In the following sections, these connections will be examined in detail. The foundations as well as the effects and the future challenges will be discussed. First, this chapter clarifies the terms used in the study and briefly outlines the institutional foundations of Switzerland's current VPET system. The focus will generally be on institutions and developments that are relevant for innovations. The chapter concludes with a refinement of the objectives and a description of the further procedure of the study.

Terminology and focus of the study

Vocational Education and Training (VET) refers to upper secondary education programs that lead to a formal qualification. Approximately 70 percent of an age cohort start their post-compulsory education with a VET degree (Swiss Coordination Centre for Educational Research, 2018: 107). Our study focuses in large parts on such VET degrees and their institutional framework. The Swiss VPET system also includes *Professional Education and Training (PET)* on the tertiary level, which we also briefly discuss in this study. PET is one important component of the Swiss VET system, because PET provides educational career options for VET graduates at the tertiary level. Another such career option is provided by *Universities of Applied Sciences (UASs)*. UASs are therefore also included in some parts of this study, although they formally belong to the university sector. The students of UASs are generally VET graduates and the establishment and existence of UASs has made a crucial contribution to the attractiveness and innovative capacity of the Swiss VPET system. Notwithstanding, VET programs at upper secondary level are clearly in the center of this study.

VET programs in Switzerland are mostly *dual VET programs* (a combination of practical training and vocational schooling). They are characterized by a combination of three training locations that provide education and training in accordance with an official and binding curriculum.[9] Training locations are companies (usually three to four days a week), vocational schools (usually one to two days a week) and inter-company training courses in inter-company training centers (depending on the occupation, these take on average between 16 and 30 days).

Regarding the term *innovation*, we use it broadly in this study, based on the definition in the Oslo Manual (OECD/Eurostat, 2018). In principle, we include all types of innovation in our analyses.[10] However, where the literature or empirical studies we refer to are explicitly limited to very specific types of innovation, we naturally also refer to narrower definitions.[11]

Overview of the current Swiss education system

An overview of Switzerland's whole education system with its diverse educational pathways, as well as its graduation and development options, can be found in Figure 1. A special feature of Switzerland's education system is that after compulsory schooling, it is based on a vocational and an academic strand. As the Swiss education system is structured according to the principle of "there shall be no dead-end qualifications,"[12] all upper secondary education graduates have a wide range of formal educational options at the tertiary level. This applies to graduates of VET programs as well as to individuals with a *general baccalaureate (Matura)* or an upper secondary specialized school certificate (Fachmittelschulabschluss).

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[9] Under "curriculum" in the following, we subsume everything that defines the contents of a VET program. These are the typical competences of an occupation, which are defined in the VET ordinances ("Bildungsverordnungen") and the associated detailed VET curricula ("Bildungspläne") as well as in the ordinance on the minimum requirements for the general education part of VET programs.

[10] According to the Oslo Manual, innovations are defined as follows: "An innovation is a new or improved product or process (or combination thereof) that differs significantly from the unit's previous products or processes and that has been made available to potential users (product) or brought into use by the unit (process)" (OECD/Eurostat, 2018: 20).

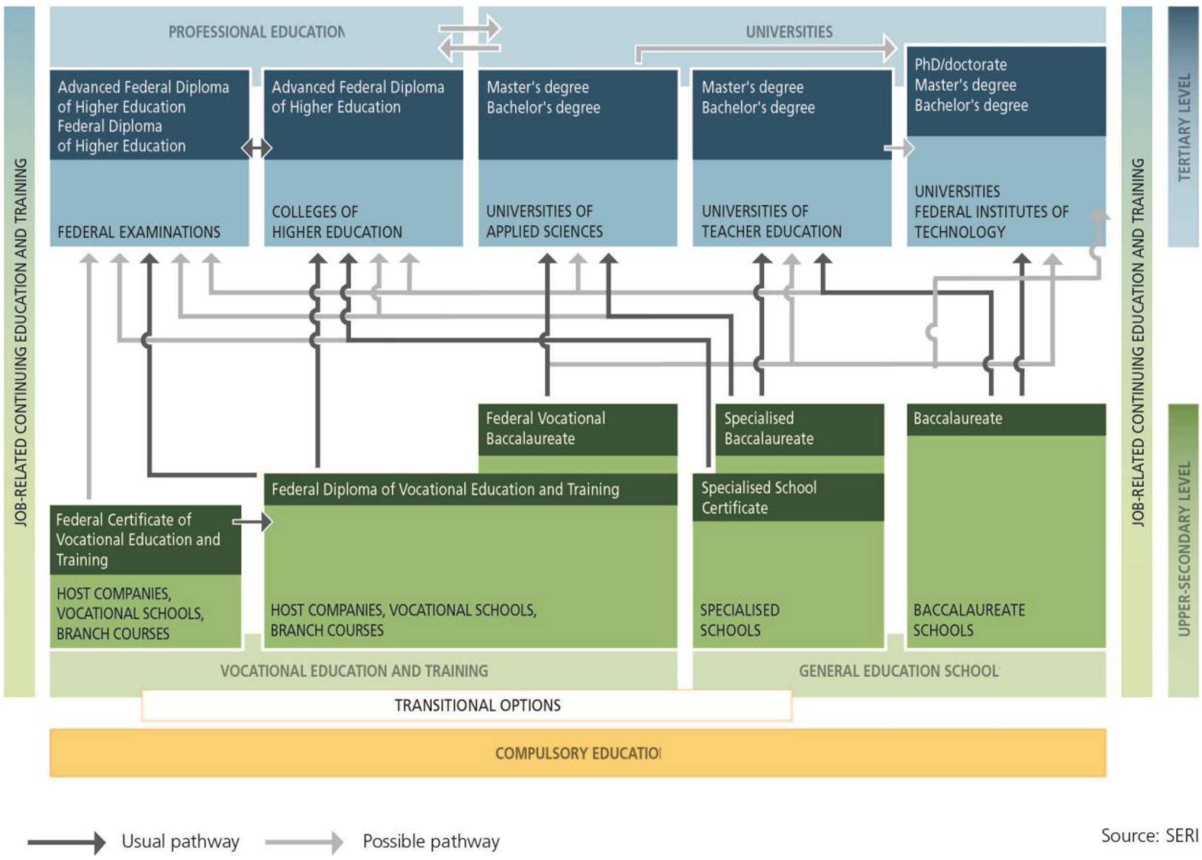
[11] For a definition of innovation and types of innovation, see Beck et al. (2016), Edquist et al. (2001), Fagerberg (2004), and Meuer et al. (2015).

[12] In German language the principle is named: "Kein Abschluss ohne Anschluss".

The diversity of Switzerland's education system that is visible in Figure 1 constitutes an advantage for the ability to innovate, as it offers different educational opportunities for the most diverse interests, abilities, preferences and requirements of the world of work.[13] The different educational opportunities are at the same time systemically interconnected and thus ensure a high degree of permeability. Permeability and connectivity within the education system and the labor market are themselves prerequisites for lifelong learning processes, which in turn are a prerequisite for the implementation of innovations (especially in aging societies) (see Chapters 3 and 4 for more details). Switzerland's education system, with its two strands, its diversity and its systemically guaranteed permeability, thus lays the skills foundation for innovation in companies.

However, as innovative economies are constantly facing new challenges, the development capacity of the VET system itself is also crucial, as will be discussed below.

Figure 1: The Swiss education system[14]



Source: State Secretariat for Education, Research and Innovation
https://www.sbfi.admin.ch/sbfi/de/home/bildung/bildungsraum-schweiz/das-duale-system.html

[13] Further information on the Swiss education system can be found, for example, in the 2007, 2010, 2014 and 2018 education reports of the Swiss Coordination Centre for Research in Education, on the website of the SERI (https://www.sbfi.admin.ch/sbfi/de/home/bildung/hbb/allgemeine-informationen-ep.html) or on the Swiss education server (http://bildungssystem.educa.ch/de).

[14] *Federal examinations* include PET examinations and advanced PET examinations. *Colleges of Higher Education* refer to PET colleges. *Branch courses* are inter-company training courses.

Recent developments in the Swiss VPET system that are relevant to innovation

As a schematic overview of the historical developments of the Swiss education system by the State Secretariat for Education, Research and Innovation shows, the education system (as well as the research and innovation system) has undergone continuous change since its beginnings (cf. State Secretariat for Education, Research and Innovation, 2018).[15] In the following, we outline the reforms that, on the one hand, are related to VPET and, on the other hand, have directly or indirectly influenced the innovation capacity of the Swiss economy.

A substantial change in the Swiss VPET system occurred in the 1990s, when Universities of Applied Sciences (UASs) were established. One of the aims of these new educational institutions was to increase the attractiveness of the VPET sector and to provide new career opportunities for apprenticeship graduates.[16] At the same time, the establishment of UASs was intended to promote cooperation between the private sector and research institutions. Their focus on application-oriented research and development (R&D) was intended to increase (regional) economic and innovative strength (cf. Chapters 2 and 3). Prior to the founding of UASs, the vocational baccalaureate, which serves as an admission requirement for UAS studies, was also newly regulated.[17]

One of the most important changes, however, was the *Federal Vocational Education and Training Act (Federal VPET Act, Berufsbildungsgesetz (BBG))*, which came into force in 2004 and is still in force today. For the first time, this act regulated all VET occupations in a uniform law. With this act, not only were all old training regulations replaced by new VET ordinances but also a standardized and continuous curriculum update process was established to keep VET programs systematically up-to-date. The law also regulates the necessary *VET-partnership*[18] *bodies*. The Federal Vocational Education and Training Act (BBG) is thus central not only to the strategic management of VPET but also to the innovative strength of the VPET system itself (for details, cf. Chapters 2 and 3).

Aims of this study

The following in-depth analyses of the Swiss VPET system aim to identify the structural characteristics of the VPET system and its institutions, processes and actors that are important for Switzerland's innovative capacity. We do not claim to provide a complete analysis of all aspects of the Swiss VPET system, which of course can go far beyond the question of innovation and which are analyzed in other contexts (see, for example, the comprehensive research scopes and publications of the various Swiss Leading Houses on the Swiss VPET, i.e. research centers financed by the SERI).[19]

The starting point for our analyses is that the contribution of VPET to innovation results from the interaction of three different levels, which we will examine individually and in more detail below. These are first, the systems level (including the state[20]), at which the overall system and the school-based training components are controlled; second, the company level, which is relevant for the quality and quantity of training in the company; and third, the individual level, which determines above all which talents are available for VET and will be trained. The analyses will generally focus on the specific aspects of the VPET system in Switzerland and on empirical analyses based on Swiss data. However, where there are generalizable relationships or where no suitable Swiss data are available, we also refer to findings from international comparative studies (for an overview, see Wolter & Ryan, 2011) and from foreign education systems (especially from similar VET systems or—where dysfunctionalities are concerned—from systems without VET).

Although the aim here is to present causal effects of different characteristics of the VPET system on innovation, in many cases, due to the lack of data, there are no causal analyses in the strict sense available (cf. Box 1); in this case, we also present simple descriptive evidence and draw accordingly cautious conclusions.

[15] See timeline in Appendix 5, and https://www.sbfi.admin.ch/sbfi/en/home/seri/chronology-of-education-research-and-innovation-in-switzerland.html.

[16] A comparatively young type of school is the PET colleges, which have been in existence since 2005 and have evolved from technical schools, among other things, and in the meantime have seen a sharp increase in the number of graduates. Compared to the Federal PET Diploma Examinations and the Advanced Federal PET Diploma Examinations, the PET colleges have a more general orientation; compared to the UASs, there is no research, and they are oriented towards the labor market.

[17] The vocational baccalaureate was subsequently repeatedly reorganized and moved, for example, from fields (Fachrichtungen) to core areas (Schwerpunkten) to increase the flexibility of its graduates (see, for example, Caduff, 2014).

[18] VET in Switzerland is a joint responsibility of the federal government, the cantons and the Organizations of the World of Work. They work together in the so-called VET-partnership (for more details see chapter 2).

[19] Research contributions to Economics of Education can be found in particular at http://www.educationeconomics.uzh.ch/en.html. Research results in other fields can be found in other Leading Houses financed by the SERI (see www.sbfi.admin.ch/leading-houses) and in the SKBF database on Swiss educational research (http://www.skbf-csre.ch/bildungsforschung/datenbank/).

[20] While primary schools, general baccalaureate schools (Gymnasium) and universities fall within the competence of the cantons, VPET is regulated by the federal government and managed by the VPET partnership, i.e., with the involvement of state and economic actors (cf. Chapter 3.2). For example, the cantons are responsible for the implementation of general education, while the Confederation issues minimum regulations (Arbeitsgruppe Rahmenlehrplan Allgemeinbildung, 2006) and a VET-partnership commission examines the actuality of the contents (State Secretariat for Education, Research and Innovation, 2016).

Box 1

Central problem of empirical analyses: Identification of causal effects and unavailability of data

Identification of causal effects

The central problem in assessing the impact of VPET on innovation—and in the assessment of any economic policy measure—is the identification of causal effects.[a] Simple comparisons of the mean values of an innovation measure (e.g., patenting) between companies with and without VPET are not sufficient to prove causal effects. First, it must be ensured that there are no other possible reasons for the observed differences. A correlation between the outcome variable innovation and an economic policy measure can also occur through "reverse causality." A positive correlation between a policy measure and a firm's success may appear because an economically successful firm is generally more successful in gaining access to the policy program and not because the policy measure has a positive causal effect on the firm (Kugler et al., 2014). Other reasons may be "unmeasured or unmeasurable characteristics of the company" (omitted variables), which, however, drive the company's success.

To assess the causal effect of a policy measure, one would have to compare the firm having participated in the policy program—"with the policy measure"—with the same firm not having participated in the policy program—i.e., "without the measure (i.e., in the counterfactual situation)." However, non-participation, i.e., the counterfactual situation, can never be observed whenever a firm participated in the program. Research therefore uses econometric methods and selects suitable comparison groups to try to determine as precisely as possible what the result would have been without the policy program (an example of how to econometrically solve this counterfactual situation problem is the study by Pfister et al. (2018) on the innovation effects of the establishment of UASs).

Economic research, particularly during the last two decades, has specialized in statistical and econometric methods for measuring causal effects. These econometric methods rely on panel data, exploit quasi-experiments (such as (quasi-)random variation in the beginning of a policy program), or they perform randomized field experiments in which firms (or individuals) are randomly assigned to a policy program.[b] Under certain conditions, the different methods provide equally valid results (DiNardo & Lee, 2011).

Missing data

A further problem for the assessment of any economic policy measure is the availability of data. The different statistical methods for causal impact analyses require a good data basis.[c] Longitudinal or panel data—both for individuals and for firms—are particularly valuable for causal analyses. Moreover, the linking of different data sources can significantly improve the possibilities of econometric analyses. In Switzerland, however, the availability of such longitudinal data and the possibility of linking different data sources are restricted to a selective number of (research) questions. To combine different data sources, firm and/or personal identifiers that are consistent among the databases would be needed to jointly evaluate, e.g., education data with labor or innovation data (like for example in the recently introduced LABB data). It is also crucial that such data are easily available to researchers. Research data centers cooperating with statistical offices or governmental authorities constitute a valuable solution and have become standard in other European countries, e.g., Denmark (cf. the research data centers of Statistics Denmark, or the FDZ of IAB[d] or BIBB[e]).

Generalizability of results: Problems of national and international comparisons

A final and essential issue is the generalizability of the interpretations of empirical analyses of policy measures from different countries. As the analyses (and the economic policy measures) may depend on the specific circumstances of the country, a specific time period and specific economic conditions, the generalization of their results must take into account these particularities. Under certain conditions, theoretical predictions and empirical results may be transferable to other situations or countries, but under other conditions, they may not be transferable (Busemeyer & Trampusch, 2012; Wolter & Ryan, 2011). As countries with VPET systems function in many ways very differently from countries without VPET systems, this study focuses primarily on studies that include Swiss data and, on a case-by-case basis, studies on Germany or other countries with a VPET system. The results from Anglo-Saxon countries, however, are generally not transferable and are used only to demonstrate the lack of generalizability.

[a] The following description of statistical and econometric methods for estimating the causal effects of economic policy measures relies on Boockmann et al. (2014), Kugler et al. (2014) and Webbink (2005). See Boockmann et al. (2014) for a discussion of valid impact analyses and their institutional prerequisites. See Kugler et al. (2014) and Webbink (2005) on measuring causal effects in education economics.

See Chapter A2, "Promoting innovation more efficiently through the evaluation of policy measures," on the use of randomized experiments to assess innovation policy measures (Expert Commission on Research and Innovation, 2014).

[b] The aim of these procedures is to approximate randomized experiments by exploiting natural variation in the assignment of the policy measure. One source of natural variation, for example, is thresholds imposed by administrations: Individuals just above the threshold (and with access to the measure) are compared with those just below (and without access to the measure), as these two groups are very similar in all relevant characteristics except participation in the measure. This procedure—known as regression discontinuity design in the literature—assumes (and this assumption is usually carefully discussed and justified) that individuals accidentally end up above or below the administrative threshold. The instrumental variable (IV) approach eliminates those factors that involve endogenous participation in policy measures. The IV approach thus uses an instrumental variable that determines participation in the policy measure but shows no direct relationship to the outcome variable. The difference-in-differences approach focuses on the outcome of individuals (or firms, cantons, etc.) before and after the introduction of a policy measure, differentiating in both periods individuals participating and not participating in the policy measure/program. If a policy measure is (quasi-)randomly assigned to the individuals, the comparison of the differences before and after participation shows the causal effect of the policy measure. Fixed effects estimations exploit longitudinal data and eliminate unobserved and time-constant factors of individuals that could influence the result variable (e.g., fluid intelligence). The similarity of the comparison groups can be further increased by means of matching procedures, which arrange individuals according to their observable factors.

[c] A central factor in the evaluation of economic policy measures is not only a careful ex ante analysis, but also an in-depth ex post analysis because precisely determining the effect of a (future) policy measure in advance is not possible. In contrast to the USA, however, most European countries focus primarily on ex ante analyses and less on ex post analyses (Boockmann et al., 2014).

[d] IAB: Institut für Arbeitsmarkt und Berufsforschung, Nürnberg (Institute for Employment Research).

[e] BIBB: Bundesinstitut für Berufsbildung, Bonn (Federal Institute for Vocational Education and Training).

2 Systems level: Innovation-relevant structural characteristics of the Swiss VPET system

In this chapter, the legal and institutional framework conditions of the Swiss VPET system are briefly described, followed by a detailed analysis of the system's innovation-relevant characteristics and their impact.[21] The analyses are based mainly on economic literature, but in individual cases, they also include political science, sociology, pedagogy or other related disciplines.[22]

Particularly, international comparative studies have pointed out that two aspects are important to the functioning of a VPET system. A first central aspect is the participation of all important actors. In Switzerland, the VPET system involves not only the state but also the Organizations of the World of Work (*Organisationen der Arbeit (OdAs))*. These can include: occupational associations, sector/industry associations, employers' associations and employee associations such as trade unions as well as training providers, including companies.[23] OdAs play a central role in, among other things, the design and reform of VPET programs (cf. Chapters 2.2 and 2.4). In addition, companies are another important player in the vocational training system and, where collective agreements exist, trade unions. Companies provide apprenticeship positions and thus make a substantial contribution to the administration, training and financing of VET (cf. Chapter 3).

A second important aspect of the VET system relates to the way these different actors interact with each other.[24] International comparative studies argue that successful VET systems are characterized by a corporatist organization of actors from government and the labor market (see, e.g., Bolli et al., 2018a; Busemeyer & Trampusch, 2012; Wolter & Ryan, 2011). A characteristic feature of Switzerland is that in addition to the state[25], a variety of *OdAs (*Organizations of the World of Work), including companies, are involved in the system. The role of OdAs is legally defined by the Federal VPET Act. They work together as partners, each with a distinct role, in the so-called *VET-partnership (Verbundpartnerschaft)*[26]. The framework conditions and details of this corporatist organization in Switzerland are analyzed in more detail below.

2.1 Legal and institutional framework of the VPET system in Switzerland

In Switzerland, the regulation of VPET falls within the competence of the federal government. VPET is thus uniformly regulated throughout Switzerland in terms of its most important principles, specifications and training content (Federal Constitution, Art. 63). In addition to the federal government, the cantons and the Organizations of the World of Work (OdAs) are other players in the VPET system. In accordance with the Federal VPET Act (BBG, Art. 1, Para. 1), they take on this task as partners in the so-called VET-partnership (Verbundpartnerschaft) (State Secretariat for Education, Research and Innovation, 2017a).[27]

The federal government is responsible for the strategic monitoring and development of the VPET system. On the one hand, it is responsible for the legal foundations, such as the Federal VPET Act and the associated VET ordinances. On the other hand, at the request of the OdAs, the federal government issues new or revised VET ordinances (BBG, Art. 19) and approves examination ordinances for PET (BBG, Art. 28) as well as framework curricula for PET colleges (MiVo-HF, Art. 8, Para. 2). The federal government thus plays an important role in ensuring the quality and further development of VPET in Switzerland. The State Secretariat for Education, Research and Innovation (SERI) acts as the federal competence center for

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[21] In addition to innovation-relevant features, the development of the system itself is important. This requires strategy discussions and institutionalized processes at reasonable intervals, such as those suggested by the VPET strategy process 2030 (Berufsbildungsstrategie 2030).

[22] Given the advantages and disadvantages of microeconomic studies, we also include the results of other, complementary literature strands in our analyses (see also Wolter & Ryan, 2011).

[23] The Organizations of the World of Work (OdAs) are associations or organizations from the world of work (labor market) and have legally defined roles in the VPET system that are laid down in the Federal VPET Act. As a rule, they are nationwide organizations, i.e., employers' associations, trade unions, occupational associations and sectoral associations. However, if there are no such organizations in a particular VPET field, the federal government may involve other bodies, e.g., organizations active in a similar VPET field or regionally active organizations in the respective VPET field, as well as interested cantons. According to the SERI (2018), OdAs can be divided into two groups: 1. occupational associations and sectoral associations and 2. VPET partners and other organizations and providers of VPET. In a broad sense, companies as providers of VPET can thus also be counted as OdAs (cf. SERI, 2017b).

[24] See also Bolli et al. (2018a), Busemeyer & Trampusch (2012), Rauner (2010), and Wolter & Ryan (2011).

[25] The state organizations are the actors, and the legislative procedures are the associated legal institutions.

[26] In Switzerland, VET is a responsibility of the federal government, the cantons and the Organizations of the World of Work. These three VET partners work together in the so-called VET-partnership. Together, they are committed to high-quality Vocational Education and Training. In addition, they aim to provide a sufficient number of VET training places in Switzerland. The different tasks of the three VET partners are clearly defined. The federal government is responsible for strategic control and development, the cantons for implementation and supervision. The Organizations of the World of Work (OdAs) provide VET content and VET training places.

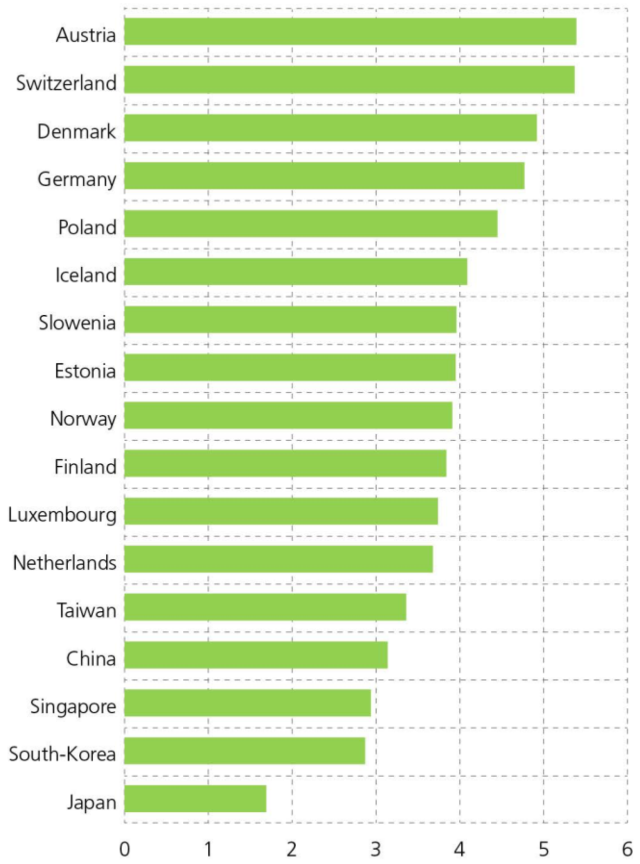
[27] The Federal VPET Act (BBG) and the VET ordinances (BBV) regulate the responsibilities of these actors and the principle of the VET-partnership. As guidelines for their cooperation, the VET partners (Verbundpartner) jointly developed a "Charter of the VET Partnership in VPET" in 2016 based on the four principles "Planning, Deciding, Implementing, Evaluating" (cf. in this context https://www.sbfi.admin.ch/sbfi/de/home/bildung/berufsbildungssteuerung-und--politik/verbundpartnerschaft.html).

national (and international) matters related to education (including VPET), research and innovation policy (State Secretariat for Education, Research and Innovation, 2017a). [28]

The cantons are responsible for the implementation, i.e., the enforcement (by means of enforcement regulations), of the Federal VPET Act and the PET ordinances as well as for operational and educational supervision (BBG, Art. 24). The task portfolio of the cantonal offices for Vocational Education and Training includes, among other things, training counseling and supervision (approval of training contracts between learners and companies, granting of training permits to companies, supervision of the apprenticeship relationship, etc.), the organization and supervision of vocational schools and PET colleges, *Qualification Procedures*[29] (organization, implementation and supervision of intermediate and final examinations), and VPET marketing and career counseling regarding VET programs, educational pathways and educational career options. *Intercantonal coordination* is carried out by the *Swiss Conference of Cantonal Ministers of Education (EDK)* and the *Swiss Conference of VET Offices (SBBK).*

The Organizations of the World of Work (OdAs) are responsible for educational content and VET positions. While the umbrella organizations (at the national level, for example, the Swiss Confederation of Employers or the Swiss Confederation of Trade Unions) are primarily active politically with regard to overarching issues of VPET, the professional and sectoral associations deal with the concerns of their respective professions or sectors. They are in charge of the revision and the creation of VET ordinances and the associated VET curricula. They therefore define the content of occupational curricula and take the initiative with regard to reforming existing and creating new occupations. [30] They often also run training centers (in which *inter-company training courses* take place), provide experts for the so-called *"Qualification Procedures"* and are involved in both the design and implementation of VET and PET examinations. Their influence on the content, conceptual and strategic issues of VET and PET is therefore decisive.[31]

Figure 2: Country comparison Education-Employment Linkage Index (EELI-Index)



EELI-Index: Index representing the linkage between the labor market and the VPET system on a scale from 0 (none) to 7 (high).
Source: Illustration based on Renold et al. (2016)

[28] In addition, the federal government issues framework curricula for the general education part of the VET programs and for the vocational baccalaureate. It approves and/or recognizes examination regulations and framework curricula in the area of PET examinations, PET Diploma Examinations, and PET colleges, and it is responsible for the framework curricula of VPET trainers and examination experts and recognizes the corresponding courses. In addition, the federal government is responsible for information and documentation as well as for the comparability and transparency of programs throughout Switzerland. It is also responsible for the training of occupational, study and career guidance counselors and recognizes the corresponding education programs (see State Secretariat for Education, Research and Innovation, 2017a).

[29] "Qualification Procedure" is the generic term for all procedures used to determine whether a person possesses the required competences laid down in the VET ordinances of each occupation. The occupational competences are proven by one overall final examination, a combination of partial examinations or other Qualification Procedures recognized by the SERI. The most important Qualification Procedure is the final examination at the end of basic vocational training.

[30] The Organizations of the World of Work together with representatives of the SERI and cantons have a seat on the *Committee for Occupation Development and Quality* that is responsible for the reforms of the education ordinances.

[31] Companies, which are also considered OdAs, provide apprenticeship positions for the occupational practice part of dual VET and thereby secure their current and future supply of skilled workers (State Secretariat for Education, Research and Innovation, 2017a). There are also other commissions, actors, committees and conferences that are important for VPET. These include the *Swiss Conference of Cantonal Ministers of Education (EDK)*, the *National VPET High-Level Meeting* and the *VPET Partnership Conferences*. The Swiss Conference of Cantonal Ministers of Education (EDK) is a political body formed by the 26 cantonal ministers of education. The cantons have the main responsibility for education in Switzerland. They coordinate their work at the national level through the EDK. The foundation for the work of the EDK is legally binding, intercantonal agreements, known as "concordats" (cf. http://www.edk.ch/dyn/11553.php). The *VPET High-Level Meeting* takes place annually. The federal councilor invites top representatives from the federal government, cantons, politics and business to discuss current issues and challenges in VPET. The annual meeting is dedicated to political and strategic exchange. The agenda items are jointly planned by the VPET partners. Approved projects are implemented jointly. The *VET-Partnership Conference* takes place once a year. Participants from the federal government, cantons and organizations from the world of work meet to jointly develop Vocational Education and Training in Switzerland. The *VPET Partnership Conference* is a work meeting and offers a platform to jointly deal with a defined VPET issue in depth.

Linking the education system and the labor market as a key element

The VET-partnership between the federal government, the cantons and the OdAs is one of the central characteristics of the Swiss VPET system, as it ensures the link between the education system and the requirements of the labor market (the economy), which is important for labor market success and innovation. As Figure 2 shows, Switzerland is in an excellent position in terms of an index for linking the labor market and the VPET system. The index ranges from 0 to a maximum of 7. Switzerland has a value of more than 5 and ranks first with Austria in an international comparison (see Figure 2 and cf. also Caves & Renold, 2016; Swiss Coordination Office for Education Research, 2018).

This systemic linkage of the education system and the labor market has two advantages. First, information and resources from both domains can be systematically used for a future-oriented development of the overall system and individual occupational profiles. Second, the institutionalized linkage of the VPET system with the labor market creates strong incentives for a continuous and future-oriented development of VPET. This is because the innovative companies that are integrated into VPET development are continuously exposed to market competition and have a strong interest in the provision of up-to-date, future-oriented training contents that help them to stay competitive. This results in continuous updating of the occupational curricula of the relevant VET programs.

2.2 Ensuring future-oriented occupational competences by regularly updating VET curricula

A key prerequisite for the innovative capacity of an economy is a workforce whose qualifications are state-of-the-art after the initial education and provide a basis for lifelong learning. This enables workers to cope with continuous new challenges throughout their working lives. These prerequisites must be ensured through, among other elements, appropriate curricula in VPET.

These curricula contain methodological and social competences on top of technological and professional competences. To ensure sufficient adaptability, two conditions must be met. First, curricula must be future oriented. The technical competences defined in the curricula must correspond to the latest technological standards of the respective occupation.[32] This ensures that the trained workforce can be employed productively in modern production processes and that workers are open to and prepared for the introduction of new technologies and processes. The prerequisite for such future-oriented curricula is that the contents of the curricula are continuously updated by means of a systematic curriculum updating process.[33] Second, the methodological and social competences defined in the curricula must lay the foundation for lifelong learning (BBG, Art. 15, Para. 2) and must help VET graduates to cope with—or ideally even promote—necessary technological or institutional adaptations in the future (cf. also Chapters 4.2 and 4.3). With regard to methodological and social competences, too, the contents of the curricula must also be continuously updated through a systematic curriculum updating process.

In Switzerland's VPET system, such a process for the systematic updating of curricula is firmly established through various mechanisms and through the institutionalized participation of various actors (see the handbook "Prozess der Berufsentwicklung in der beruflichen Grundbildung" (State Secretariat for Education, Research and Innovation, 2017b)). On the one hand, VET ordinances prescribe a periodic review during which the VET ordinances and the respective occupational curricula must be continuously reviewed (at least every five years). The review must take account of new technological, economic, ecological, social, cultural and didactic developments (BBG, Art. 15, Para. 2). On the other hand, there are firmly established processes and institutions in place to fulfill this task. The task is the responsibility of the *Committees for Occupation Development and Quality (Kommissionen B&Q)*, each of which is a commission made up of representatives of the SERI (in accordance with VET ordinances, BBV 2003, Art. 12, para. 1), the OdAs, the cantons and the specialized teaching staff (in accordance with the respective VET ordinances).[34] The commission's responsibilities, among other things, include reviewing the occupational requirements and the goals of the particular VET program. It is also responsible for the quality of the program.

[32] The basis for such an orientation is laid down in the BBG of 2002. Accordingly, VET is geared towards the world of work. It provides the knowledge, skills and competences required for the tasks that must be performed in an occupation. The aim of a VET program is to ensure that its graduates are able to carry out their occupational activities reliably and competently (BBG, 2002, Art. 15, Paras. 1, 2).

[33] Zbinden (2010) and Wettstein et al. (2014) also point out that due to the orientation of VET towards the world of work, changes in occupational activities also require changes in the associated VET programs. VET programs must therefore not only be up-to-date (in terms of content, vocational pedagogy and didactics) and able to adapt rapidly to societal, technological and economic change but also improve employability. Therefore, they must also promote employability skills such as work motivation, team competence and the ability to deal with conflict. They must also teach competences that are valid in the long term, are relevant for lifelong learning and can be transferred to other areas of application (BBG, 2002, Art. 15).

[34] Furthermore, there are other experts, such as the leaders of inter-company training courses, sitting on the commission; in addition, experts or pedagogical advisors from the *Swiss Federal Institute for Vocational Education and Training (SFIVET)* can be called in if necessary. The composition of the commission depends on the associated VET ordinance.

In principle, the revision or development of new VET programs takes place in five phases. These phases are first schematically described below and then illustrated using two actual case studies: the revision of mechanical and electrical engineering (MEM) occupations in 2009 (Box 2) and the revision of the dental technician occupation in 2018 (Box 3).

Box 2

Curriculum updating case study "MEM occupations": Updating of "Automation Engineer (Automatiker) EFZ" and "Polymechanic (Polymechaniker) EFZ" and innovation (2009)[a]

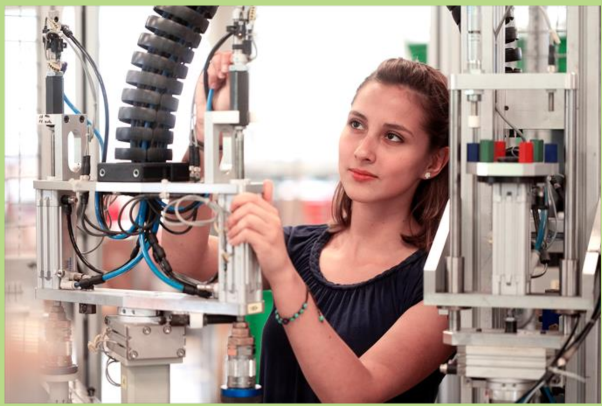
Swissmem is the largest industry organization in Switzerland and the leading association for small, medium-sized and large firms in the Swiss mechanical and electrical engineering (MEM) industries and the related technology-oriented sectors.[b] Together with Swissmechanics, *Swissmem* is responsible for updating or creating technical occupations in the MEM sector. More than 1,000 companies, of which the majority are large, are members of *Swissmem*.[c] The annual sales of the MEM industries amount to more than CHF 80 billion, of which CHF 65 billion are generated abroad. In Switzerland, 320,000 employees and 20,000 apprentices work in these industries. The members of *Swissmem* consist of innovation driving companies of all firm sizes[d] as well as companies at a certain distance from the innovation frontier. Together, these firms constitute an innovation ecosystem that makes the Swiss mechanical and electrical engineering (MEM) industries among the most innovative in the world.

The Swiss MEM industries have a service and competence center for VPET, the Vocational Education and Training Division, which consists of more than 20 employees. An important task area is the new and the further development of the VET programs "Apparatus Engineer EFZ"[e] (4 years), "Automation Engineer EFZ" (4 years), "Automation Technician EFZ" (3 years), "Electronics Engineer EFZ" (4 years), "Design Engineer EFZ" (4 years), "Polymechanic EFZ" (4 years), "Mechanical Technician EFZ" (3 years) (all EFZ trainings), and "Mechanical Assistant EBA"[f] (2 years).[g] In addition, the Vocational Education and Training Division develops, produces and distributes teaching material on MEM VET programs for both vocational schools and companies.

An essential element of the innovative capacity of the MEM industry is the continuous, future-oriented development of its VET curricula. The following section encompasses concrete case studies—particularly on the reform of the VET programs "Automation Engineer EFZ" and "Polymechanic EFZ" from 2009[h]—that illustrate the variety of measures ensuring the actuality and the future orientation of curricula in the MEM industries.

Key elements of the 2009 reform of the MEM occupations "Automation Engineer EFZ" and "Polymechanic EFZ"

The responsibility for the continuous adaptation of the VET programs lies with the ***Committee for Occupation Development and Quality*** *(SKOBEQ-MEM)* in the machinery, electrical and metal industries of the MEM sector.A precondition of success for the curriculum updating process is a broad support in the sector, the participation of innovative companies and the early involvement of all actors relevant to the implementation of the curricula.



"Automation Engineer EFZ"
Photo: *Swissmem*

Broad support

The above-mentioned committee, the SKOBEQ-MEM, includes in addition to the members of employers' associations (*Swissmem*, Swissmechanic, SwissPrecision, "Verband der Schaltanlagen und Automatik Schweiz" VSAS and "Schweizerischer Verband der Elektromaschinenbauer" SEMA) as one important knowledge source and decision-maker, the representatives of employee associations (SYNA, UNIA), the state (SERI and SBBK) and the vocational schools. This broad support ensures not only that the new or updated curricula are future oriented and in high demand on the labor market but also that they are practically feasible and implementable in the company and the school.

Early involvement of all actors

The involvement of all important decision-makers takes place at a very early stage, i.e., in the first conceptual phase of a newly developed or an updated occupation. How this is achieved will be illustrated in the following by using the example of the *Swissmem* VET programs "Polymechanic EFZ" and "Automation Engineer EFZ" curriculum.

Even before the concrete work on the VET curricula updating started, *Swissmem* conducted a broad survey on future requirements and the context of the VET programs to be reformed (cf. Swissmem, 2004). The survey involved 181 participants, who included the following actors and decision-makers: *Swissmem* member companies (66 percent), public apprenticeship companies (7 percent), inter-company training centers (12 percent), vocational schools (14 percent), examination boards/chief expert committees (1 percent)[i] and the VET Office (1 percent).

Identification of expected developments in occupational tasks, work organization and methods, labor market prospects, and necessary competences for innovation

First, all participants were asked to assess the future development of the industry, the occupational field and the VET programs, e.g., of “Polymechanic EFZ” or “Automation Engineer EFZ”.[j] The survey included questions regarding, for example, the main technological changes, working methods and organizational forms that companies expected in the next three to five years.[k]

With regard to the expected new technologies for the VET programs of “Polymechanic EFZ” and “Automation Engineer EFZ”, the survey results showed, for example, that computer-controlled machine tools, automation, programmable logic controllers and software methods were gaining in importance, while classic manual manufacturing would continue to lose relevance in the future. Regarding working methods, the respondents expected changes due to increasing (global) competition, such as faster throughput times in production, shorter delivery times, lower production costs and cooperation with business partners all over the world (Swissmem, 2004: 3–4).

The expected new developments were collected and translated into a new catalog of requirements for the VET programs “Polymechanic EFZ” and “Automation “Engineer EFZ”. Accordingly, the newly developed VET curricula and VET ordinances included not only specific competences for new technologies such as programmable logic controllers (PLCs) but also generic competences such as independence, self-responsibility, flexibility and intercultural communication.

Second, the survey collected opinions on the development of future jobs for graduates of the occupational profile. The companies were asked to rate the future relevance of their main activities—e.g., building prototypes, carrying out tests, and manufacturing workpieces—but also about their future potential for apprenticeship training places in various fields of activity such as design, prototype construction, automation and assembly. The results show that the majority of previous activities continue to be rated as relevant. However, there has been an increase in importance, for example, in “Processing orders or projects” (51 percent expected an increase), “Developing design solutions and producing technical documents” (41 percent), “Building prototypes and carrying out tests” (42 percent) or “Participating in the planning and monitoring of production processes” (40 percent). Activities that decrease were generally mentioned less frequently; among these are “manufacturing workpieces” (14 percent expect a decrease), “developing design solutions and creating technical documents” (21 percent) and “planning and monitoring production processes” (17 percent). The latter seemed to be rather uncertain or to develop differently depending on the company, since both an increase and a decrease were expected comparatively frequently (Swissmem, 2004: 8). In addition, the survey asked about the future relevance of different generic competences. It is striking that the majority of respondents expect an increase. Particularly pronounced increases were expected in quality orientation and efficiency (77 percent expected an increase), independence (76 percent), flexibility (76 percent), ability to deal with changes (75 percent), ability to learn (66 percent) and working methods (66 percent). In contrast, the least significant increase was expected, for example, for company specific competences (35 percent) (Swissmem, 2004: 13).

Third, the survey also asked about opinions on the future relevance of concrete training elements, such as basic occupational skills modules (e.g., measuring and testing technology, production technology, and module assembly) compared with skills cutting across occupations (learning ability, occupational safety, etc.), or the relevance of inter-company training courses and vocational schools or various elements of the Qualification Procedures (final examination elements). The results showed that the existing educational concept should basically be maintained, i.e., a broad practical basic training module in the first half of the VET program and specialized training modules in the second half of the apprenticeship, a program duration of four years, and two proficiency levels but with a greater distinction (the lower level G lowered even more). In addition, public apprenticeship training workshops will form training alliances with private training companies (Swissmem, 2004: 9).

Development of new occupational profiles with the help of occupation experts from companies

Based on these results, an inter-association working group of vocational training experts then developed the occupational profile, described the occupational characteristics and activities, and designed the concrete new VET curricula and VET ordinances. The VET experts in the working group are, for example, workers who have themselves undergone a respective VET program, trainers in companies and inter-company training courses (VPET professionals[l]), experts in Qualification Procedures and teachers at vocational schools; working group members also include development and production managers who have special insights into the latest technologies and production processes. The work of this group is thus again broadly supported in the industry. Furthermore, the composition of the VET experts reflects the balance between, for example, the regions of the country, the size of the company or the sectors within the occupational field. *Swissmem* can thereby draw on a large pool of VPET professionals and VET experts for the composition of the working group, as concrete proposals for potential members for the working group, e.g. for the "Polymechanic EFZ", were already sought in the survey. More than half of the firms (a total of 82) offered to delegate an expert to the working group, i.e., many more than can be included (Swissmem, 2004: 2).

The inter-association working group describes the everyday professional reality in an activity analysis. A comparison of the current situation with the new occupational expectations shows which occupational competences had been recently added and which occupational competences were no longer applicable and may therefore cease to apply in the future.

The newly developed occupational profiles were then sent for consultation to the companies and all organizations in the MEM industries. The consultation was conducted in spring 2007, and at the same time the drafts for the VET ordinances and VET curricula for the following occupations were evaluated: "Automation Engineer EFZ" (4 years), "Electronics Engineer EFZ" (4 years), "Design Engineer EFZ" (4 years), "Polymechanic EFZ" (4 years), "Automation Technician EFZ" (3 years), "Mechanical Technician EFZ" (3 years) and "Mechanical Assistant EBA" (2 years).

The most important results of the consultation were then summarized, their implications for the VET ordinances and VET curricula presented and the corresponding solutions proposed (cf. Swissmem, 2007). In this step, for example, the contents of the basic and specialized training courses for all VET programs were optimized, and the training objectives for "Automation Engineer EFZ" and "Polymechanic EFZ" were partially reduced. In addition, it was newly established that companies when training "Polymechanics EFZ" have a choice among several specialized training modules. Moreover, during the basic training, participants can train on conventional and/or numerically controlled machine tools, which gives the training companies the necessary flexibility in machine manufacturing; however, during the inter-company training courses "Machine Manufacturing Technology," all apprentices are taught the basic skills in both conventional and numerically controlled manufacturing technology. Manufacturing, testing and commissioning of programmable logic controllers remain part of the basic training for all "Automation Engineers EFZ" (cf. Swissmem, 2007).

Changes also affected, for example, the Qualification Procedure, i.e., all interim or final examinations. It was decided that interim examinations would generally be conducted towards the end of the second year of training (required by the cantons), that "Polymechanics EFZ" would be able to choose between conventional or CNC manufacturing processes in the "machine manufacturing technology" module of the interim examination, that the minimum duration of the Individual Practical Work (IPA) would increase from 24 h to 36 h, that the subject "Technical English" will no longer be tested separately but rather in an integrated manner e.g. by formulating technical or professional tasks in English or by using excerpts from original English documents in the occupational competence examinations (cf. Swissmem, 2007).

After a respective adaption of the VET ordinances, VET curricula and numerous other normative educational documents (annexes to the VET curricula), it is possible to apply for a ticket to initiate the legal implementation of the reform. In the case of the MEM reforms mentioned above, the application was submitted in summer 2007 to the Federal Office for Professional Education and Technology (OPET) (now the State Secretariat for Vocational Education, Research and Innovation (SERI)). The ticket is a prerequisite for the consultation process with the federal offices and the cantons, which in turn is a prerequisite for the enactment of the new VET ordinances and VET curricula. For the MEM occupations, OPET issued the seven updated MEM VET programs on 1 January 2009, five years after the first survey was conducted to initiate the reforms.

"Polymechanics EFZ"
Photo: *Swissmem*

Results: Updated occupational profiles at a higher qualitative level

As a result, the occupational profile "Automation Engineer 2009", for example, included the following new components: programming of control systems, which is required above all in development; programming of parameters, which is used mainly in application contexts; and general knowledge of programmable logic controllers (PLCs). VET graduates are now able not only to control and maintain programmable logic controllers but also to program the system control themselves. Apprentices not only program simpler control systems, such as cable cars, but also complex automation systems, such as filling lines for pharmaceutical products. In the curriculum of "Electronics Engineers EFZ" the programming of microcontrollers was included as a new component; these apprentices as well will thus not only utilize microcontrollers or search for errors but also program them themselves. With these additions in the occupational profiles, VET programs of the “Automation Engineers EFZ” and “Electronics Engineers EFZ” have reached a new quality-level as, for example, the programming of system controls or microcontrollers were not part of the occupational profiles in the past. In the occupational profile “Polymechanic 2009”, additional fields of activity were included, e.g., “assembling and commissioning automated systems” or “maintenance of aircraft”; English lessons were expanded from 120 to 160 lessons; and the standards for methodological, social and personal skills were reformulated.

With the incorporation of these new competences into the updated VET programs, it will in the future be possible to employ “Automation Engineers EFZ” or “Electronics Engineers EFZ” in jobs that are in foreign countries partly occupied by engineers with university degrees.

For the future, from today’s perspective (2018), the next technological changes are already foreseeable. These will be analyzed and taken into account in the next curriculum updating round (2018–2023). Future topics will cover among others “Industry 4.0”—following the computer-controlled machines and control systems of recent decades. This will include, for example, the increasing interconnectedness of industrial processes across the entire value chain and the associated interfaces and communication, the computerization of all technical components and systems (“Internet of Things”) and new manufacturing methods such as “Additive Manufacturing.”

Incentives for companies to participate in the curriculum updating process

As the above examples show, companies are closely involved in the updating of occupational curricula and make substantial contributions at various stages of the updating process. In this context, the question arises as to what incentives companies have to participate in this comparatively costly process with substantial contributions (especially regarding the delegation of personnel). This is particularly puzzling as the *Swissmem* survey shows that there is generally a very high degree of voluntary commitment of companies to contribute resources to the development of curricula and the shaping of the VPET system (82 out of 157 companies stated that they were ready to send experts for the curriculum development process (Swissmem, 2004: 2)).

One of the incentives, according to the companies themselves, is the high demand for well-qualified workers who can efficiently and flexibly manufacture high-quality products. Companies seem to see themselves in an active role as producers of the well-qualified workers they need themselves, and not only in the role as consumers of already educated workers, e.g., through a state-run education system.

One argument often raised in foreign countries is from the perspective of *Swissmem* industry association only of minor importance to their member companies: the argument is that non-training companies are systematically poaching graduates from training companies and that all companies therefore do not want to participate in the training of skilled workers in the first place. What are the reasons? First, the strong ties of VET graduates to their training company are an important aspect that protects against excessive quits of graduates. Second, most companies in Switzerland incur no or only bearable net costs during training, as the costs of training are largely offset by the productive contributions of the apprentices. Third, mobility between companies is even welcomed or seen as an advantage, as changes between companies are always accompanied by an increase in skills and competences—and thus to an increase in the knowledge pool in the industry as a whole. Such mobility thus constitutes a possibility of increasing the innovative capacity of all firms recruiting from this pool. The mobility of trained VET graduates is therefore in principal seen as an advantage that benefits the entire Swiss economy.

An important prerequisite for effective mobility is that apprentices receive a broad, standardized training content in their occupations, which may currently not in all parts be required in their own training company, but may become necessary later. Companies therefore deliberately invest in an ecosystem of skilled workers that, as a result, benefits all firms. This aspect is likely to become more important in the context of increasingly interconnected production processes and services, in which everyone—from suppliers via producers to the service providers—is directly interconnected (Industry 4.0); this is because at all levels and stages of this process well-qualified workers are required to exploit synergy as effectively as possible.

Potential conflicts in the updating process and possible solutions

Despite the general willingness to participate in the development of particular VET programs or the VPET system, there are nevertheless potential conflicts, as *Swissmem* (as well as other sectoral associations) always represents a large number of companies with very different characteristics and requirements. For example, the requirements differ depending on whether they are large, medium-sized, small, or start-up companies; whether they are innovation drivers or more conventional product manufacturers; and whether they have national or international ownership structures. For instance, craft-oriented companies consider their employees to work in craft occupations, while more innovative companies consider their employees to work in high-tech occupations. Naturally, the ideas about occupational profiles and the necessary reforms are at first far apart.

To solve such conflicts, *Swissmem* generally relies strongly on a good discussion culture, consensus orientation and a strong “VET-partnership”-mindset. Concrete conflicts are resolved through a joint search for creative solutions. In this context, the militia system is particularly powerful because by involving the diverse actors and thereby creating an associated identity, it helps to ensure that the identified solutions are subsequently well accepted. Also important for acceptance is that the training of trainers is guaranteed and that they will be updated to the new level.

A vivid example is provided by the updating process of the VET programs of the “Polymechanic EFZ”. Due to the conflicting interests of the different specializations and fields of activities of the companies in MEM sector, an occupational profile was created with a basic training component and several specializations. In the basic training component (in the first two years of an apprenticeship), four basic skill profiles were defined for each MEM occupation. However, in the 3rd and 4th years of an apprenticeship the specialization options provide more flexibility and offer companies more than 20 different competence profiles from which they can choose two to suit them. Since the specialization training components are very openly formulated towards the top, innovative companies are able to train their apprentices in the latest technologies and processes, and more traditional companies can concentrate their specialized training on their specific production processes. In this way, in the specific case of the “Polymechanic EFZ” program, the problem of the very different training needs of companies in different economic and technological situations was well taken into account.

Another typical source of conflict is the technological level of the VET program. Firms with different technological and economic positioning may have different preferences concerning whether an occupation should be of a more craft-like nature or whether it should be more towards high-technology production control. One solution is to offer VET programs of varying training lengths and varying requirement levels, such as “Automation Engineer EFZ” with a four-year duration, “Automation Technician EFZ” with a three-year duration and “Mechanical Assistant EBA” with a two-year duration. In the occupational profiles of the “Polymechanic EFZ”, a differentiation exists concerning the school-based education part, i.e., levels G and E. The highest school-based educational level is the vocational baccalaureate for the four-year programs.

The special role of inter-company training courses

Inter-company training courses (üK) were created because the newly created basic training component of the technical MEM occupations entails a very broad set of required competences. The aim of the inter-company training courses was to ensure that every MEM graduate possesses a common set of competences that constitute the foundation for all later specializations. As not all companies, particularly not the small companies, always have the appropriate work and machines required to train apprentices in all of the four basic skill profiles, the inter-company training courses teach the principles of all four to all apprentices.

This way, inter-company training courses can also help to close innovation-related gaps and foster the modernization of training and the diffusion of innovation across all companies participating in apprenticeship training. For example, the inter-company training courses contributed substantially to the diffusion of CNC manufacturing technologies, as it became part of the standard training for the “Polymechanics EFZ”.

In addition, there are also *inter-company training centers*, which belong to member companies who use them in various ways for their apprenticeship training. *These centers have a wide range of activities* that, for example, provide the entire basic training—partly including vocational school content—while at the same time ensuring that their training remains as close as possible to the development of the manufacturing reality of companies. They do so by continuously investing in machinery and equipment and, in some cases, by acquiring manufacturing orders from the external market or from member companies of the centers.

On the role of PET and UASs for innovation

The contribution of PET to the innovative performance of *Swissmem* member companies is less clear than the contribution of VET. Ideally, the above-mentioned technological—and other—innovations should be implemented simultaneously both in VET and in PET. However, this is currently not automatically ensured. Thus, in a better coordination between VET and PET in the *Swissmem* sector is still great potential for future developments.

Universities of applied sciences, whose application-oriented research and teaching also make an important contribution to innovation in the sector, represent a further opportunity for apprenticeship graduates to obtain higher qualifications. Their strength is the combination of sound practical vocational skills with application- and research-oriented knowledge, which promotes innovation capability, particularly, but not only, of small and medium-sized companies. For *Swissmem*, apprenticeship training therefore constitutes the basis of universities of applied sciences studies, i.e., a conditio sine qua non.

Future challenges

For *Swissmem*, one of the most important challenges for the future is filling their apprenticeship places with apprentices, especially—but not only—in demanding occupations. Particularly in demanding occupations, the number of suitable young people is currently too small. This is seen as one of the action areas for the next round of occupational reforms. Demography (i.e., fewer young people leaving school), a general increase in requirements in many occupational fields across all sectors, and a trend towards *academization (increase in attending general academic education institutions)* are seen as the causes. In this context, a VET path in general and particular VET occupations must therefore be made more attractive, especially for high ability students and ambitious young people. Opportunities to do so are seen in up-to-date technological training contents, modern and particularly women-friendly working environments, on the one hand, and good career opportunities, on the other hand.

An additional challenge sometimes arises from the increasing presence of companies with foreign ownership, particularly from countries that have no strong VET tradition. Such companies therefore often consider VET only as a cost driver but not as an investment in the skills of their workforce. Therefore, an intensified international awareness of the Swiss VPET system also helps the VPET system in Switzerland. In addition, stronger international networking activities during VET training can also help to strengthen the image of VET among apprentices. To address these issues, measures are under consideration, for example, to allow apprentices to spend several weeks abroad, which at the same time has the advantage of strengthening their intercultural skills.

[a] Key information comes from an interview with Arthur Glättli, Managing Director of Swissmem Vocational Education and Training, which took place on 09.07.2018 at *Swissmem*'s premises. Supplementary information comes from the *Swissmem* website and from the association's internal documentation, which was made available in confidence for our case study (cf. Swissmem-Resultate zu Umfrage Berufsreform, Berufskonzept, Vernehmlassungen, 2004–2007).

[b] For further details, see also https://www.swissmem.ch/.

[c] For all firms, the association provides services such as advice on knowledge and technology transfer, employment law, commercial law and contract law.

[d] Whether a firm is an innovation driver does not depend on its size. Although the majority of basic research is conducted by large firms, small and medium-sized enterprises are also active in this field. Small and medium-sized enterprises are strongly represented, particularly in applied R&D. In addition, start-ups in particular are important producers of technological innovation.

[e] EFZ (Eidgenössisches Fähigkeitszeugnis): Federal VET Diploma.

[f] EBA (Eidgenössisches Berufsattest): Federal VET Certificate.

[g] Swissmem Vocational Education and Training is also involved in the reform of the occupation “Business Management (EFZ)”.

[h] The reform process started in 2004. The newly designed VET programs started at the beginning of the apprenticeship period in August 2009.

[i] Chief experts are responsible for the organization of Q*ualification Procedures*. The Qualification Procedures, of which one part is the practical final examination, evaluate whether the apprentices possess the competences and abilities required in the associated educational regulations. The Qualification Procedures consist of school-based and firm-based examinations. Teams of examiners assess, evaluate and validate competences and employability. The involvement of chief experts and examiners in the curriculum update process ensures that experience with the implementation and the success of previous curricula is also incorporated into the reforms.

[j] The response rate to these surveys was approximately 50 percent.

[k] For the analysis of future (economic) developments, secondary literature, in particular empirical studies, was consulted.

[l] VPET professionals are experts who provide workplace training or classroom instruction within the framework of VET programs (BBG, Art 2, Para 1).

In the first phase, the occupation and its occupational competences (in comparison to other occupations) are initially analyzed (cf. also handbook “Prozess der Berufsentwicklung in der beruflichen Grundbildung” (State Secretariat for Education, Research and Innovation, 2017b).[35] On the one hand, such a VET development analysis involves an activity analysis to define the typical occupational activity profile. On the other hand, it considers the technological, economic and social developments that may have an influence on the positioning and development of the occupation.

In a second phase, based on these analyses, a qualification profile is developed (which defines the vocational competences and the difficulty level of the occupation), a VET curriculum is designed and a first draft of the VET ordinance is drawn up. The first two phases are led by the OdAs, which primarily aggregate information and findings from their member companies, especially those on the technological frontier, and incorporate them into the development of new curricula. As innovative companies in a competitive environment have a great interest in providing their employees with future-oriented competences rather than obsolete competences, the channel of participation of innovative companies in the curriculum updating process ensures that the revised curricula include, in particular, future-oriented competences geared towards the most recent innovations.[36]

In the third and fourth phases, a consistency check is carried out by the SERI. In addition, the VET ordinance, the curriculum, and the qualification profile undergo a consultation procedure to obtain feedback from the VET partners involved. The SERI approves, enacts and publishes these materials after any necessary adjustments have been made. In the fifth and final phase, the OdAs and cantons implement the new VET ordinance by, among other things, preparing school curricula, specifying examination procedures or implementing inter-company training courses. In addition, all VET partners and actors involved must be further trained or at least informed.

This cyclical reform process, in which both the current occupational profile and possible future developments of an occupation are analyzed, entails first, an adequately trained workforce and second, the diffusion of innovation knowledge. The systematic updates of the VET curricula that go hand in hand with the cyclical reform process ensure that current VET graduates are provided with state-of-the-art knowledge. This means that VET graduates are very well prepared to work in innovative companies and to drive innovation together with diversely qualified teams.

[35] Caves & Renold (2016) and Zbinden (2010) also provide a detailed description of this cyclical reform process of VET programs.

[36] The influence that these competences can have is considered in Chapters 2.5, 3.2 and 4. Among the future-oriented competences are the increasingly important soft skills (cf. Chapter 4).

Box 3

Curriculum updating case study "Dental Laboratories": Updating of "Dental Technician EFZ" and innovation (2018)[a]

The Swiss Dental Laboratories association represents leading dental laboratories in Switzerland and Liechtenstein and ensures future-oriented training and continuous education in the field of dental technology. "Dental Technicians EFZ" produce removable and fixed dentures for their customers, the dentists; offer postcare services, service features and repairs; and manufacture orthodontic appliances and splints. The industry represented by the Swiss Dental Laboratories has an atomistic supply structure. There are approximately 1,000 dental laboratories, most of which are small businesses and microbusinesses: 53 percent of the laboratories are one-person laboratories, and the largest has 25 full-time equivalent positions. These laboratories generate an average annual turnover of CHF 370,000 (see PK/VZLS/SZV, 2018).

Change in the industry through digitalization

In recent years, the dental industry has undergone profound economic and technological change, and laboratories have been confronted by eroding margins and increasing international competition. For example, imports of artificial teeth used to manufacture removable dentures have fallen sharply in recent years (from 31 million in 2012 to 22 million in 2017), while imports of already processed dentures have increased massively (from 30 million in 2012 to 52 million in 2017)[b]. This development relates partly to the technological change that has taken place in recent years. Developments in medical technology brought digital innovations to the market that fundamentally changed the work of "Dental Technicians EFZ". Dental impressions can now be digitally produced and sent to foreign countries for the manufacture of dental prostheses. These innovations affected dentists and "Dental Technicians EFZ" simultaneously and equally strong. Dentists increasingly switched to digital workflows and themselves began to produce dental prostheses "chairside," i.e., without the participation of the "Dental Technician EFZ". On the one hand, dentistry thus penetrated the dental technician market. On the other hand, "Dental Technicians EFZ" were forced to innovate and to modernize their technological equipment because their customers, the dentists, were increasingly switching to digital workflows. According to the 2017 industry statistics, digital change is progressing steadily, and the proportion of laboratories without digital technologies amounts to less than 40 percent (PK/VZLS/SZV, 2018: 53).

Digital transformation has thus caused a profound shift away from manual work towards computer-aided manufacturing. This transformation required, on the one hand, firm innovations and, on the other hand, a profound reform of the training contents of the four-year apprenticeship training "Dental Technician EFZ".

Starting point for the reform of the VET program: Growing distance between skill requirements at work and training content of "Dental Technician EFZ" due to digital innovation

The C*ommittee for Occupation Development and Quality (*Schweizerische Kommission für Berufsentwicklung und Qualität (SKBEQ)) for "Dental Technicians EFZ" is responsible for the continuous updating of the occupational curricula for "Dental Technicians EFZ". As required by law, the committee is broadly based, including representatives of all relevant actors and from all language regions (i.e., employer and employee associations (Swiss Dental Laboratories and Swiss Dental Technicians Association (SZV)), the SERI, the SBBK and the vocational teaching staff).

In 2013, the committee analyzed the objectives and reviewed the requirements of the VET program "Dental Technician EFZ" by a large-scale survey.[c] Although the results of the review were in principle positive, the vast majority of firms (81 percent) argued that the qualifications of "Dental Technicians EFZ" (occupational profile and activity profile) would no longer meet the requirements of the labor market in the future (i.e., in the next 5–10 years). In addition, an increasing discrepancy existed between the skill requirements of the occupational practice and the occupational training, particularly due to an insufficient focus on new digital technologies such as CAD/CAM, e.g., for the digital manufacture of dental prostheses (Hodler et al., 2014: 3).

Total revision of apprenticeship training with the inclusion of digital technologies

The results of the five-year review caused the SKBEQ to decide to completely revise the VET program "Dental Technician EFZ". In 2015, the committee set up a group consisting of over a dozen experts who had to do a future development analysis and an activity analysis for the occupation, as well as a development profile and an activity profile. The participants in this group represented the various language regions, the three learning locations of the companies, the inter-company training center (üK center) and the vocational schools as well as the important intersections of industry and dentistry. When selecting the representatives of the companies as learning locations, the primary focus was on VET trainers and company practitioners from successful and innovative laboratories since these laboratories were assumed to have competences that would be relevant and in demand in the future.

For the analysis of future developments in the industry and the occupation, the committee also considered changes beyond the borders of Switzerland. Although dental and prosthetic care in Switzerland continued to be excellent in terms of the quantity and quality of care, the industry was no longer the technological leader in comparison to other countries. In 2015, for example, the analysis group identified specific gaps with respect to developments in dentistry, such as the emerging “chairside” solutions, and with respect to the dental industry, where technological innovations such as scanners that enable digital rendering of dental impressions, are increasingly replacing traditional physical impressions. The analysis group further analyzed, for example, which reconstructions were no longer sent to the laboratories of “Dental Technicians EFZ”, which services (and the resulting new competences) were necessary to strengthen customer loyalty, and which competences were necessary in the transition from purely manual work to mixed service and production plans.

It was agreed that digital training was needed, but the extent to which digital training was required remained controversial. Some argued that in 10–15 years, all product categories could be produced digitally, while others argued that certain product categories could be produced digitally in the future but that complex reconstructions would still require analog techniques and craftsmanship. Given these tensions, the VET program had to be updated adequately and in a way that all stakeholders could accept.

Balancing digital and manual work in the updated VET program

To solve these conflicting interests, intensive discussions in the analysis group were necessary. Among other things, the pedagogical-didactical importance of manual (analog) work became obvious. The group unanimously agreed that new (digital) methods can be used meaningfully only if the analog craft is understood first. Manual work fosters the understanding of the use of materials and the recognition and avoidance of errors that the computer may produce. Based on this insight, a consensus was reached that manual work could not be completely replaced by digital work. It was therefore decided to maintain the manual understanding and to build on it digitally. The central educational goal, however, should also be how analog and digital workflows can be combined to generate the most efficient and high-quality product possible. This can be illustrated by an example:

In the past, “Dental Technicians EFZ” received orders from the dentist for individual pieces and processed them manually, e.g., with a metal-ceramic composite, which was layered by hand. Today, such orders are very rare and almost always occur only in aesthetically exposed areas, such as the anterior teeth. In areas where the products are not visible or hardly visible, digital elements are increasingly added to complement or replace the manual production steps.

The question of how many digital elements can be used, depends on the product category and complexity. Depending on the material and the oral situation, more or less digital technologies can be used. If, for example, the dentist wants to replace a tooth, he can render the teeth using an oral scanner and send the data record to the “Dental Technician EFZ”. Using CAD software, the “Dental Technician EFZ” can display the tooth in 3D, convert it to a digital data set and send the data set to a milling or 3D-printing unit for production.

However, if it is difficult to take a digital impression, the dentist can also make a classical impression, a physical negative. He sends this negative to the “Dental Technician EFZ”, who pours the impression into plaster and thus produces a positive, which he scans digitally and then virtually designs the dental prosthesis.

If the case is highly complex, e.g., due to problems with the jaw, the “Dental Technician EFZ” can also work on the plaster model and produce a wax-up, a draft of the dental prosthesis in wax. He then scans it and checks whether the program makes corrections.

To manufacture a dental prosthesis, there are various ways of proceeding, which range from purely manual to purely digital work. Depending on the complexity of the case, one can switch sooner or later to the digital workflow, a switch that increases the speed and reduces the personnel intensity and, consequently, increases efficiency and competitiveness. According to the updated training curricula, the apprentice will newly be taught where—or how early, respectively—to move on the spectrum between manual and digital work, depending on the complexity of the case and the product category.

In addition to manual skills, apprentices need new technological know how, such as the competence to use CAD, as well as advanced planning and organizational skills, to be able to use the manual and digital workflow in a complementary way. Moreover, as the variety of materials has increased considerably, additional material knowledge components have been added to the curriculum. In addition, customer loyalty has been systematically integrated into the new curriculum: aspects such as service, aftercare and advice for patients are covered in greater depth. Therefore, final examinations of apprentices now also mimic counseling sessions and technical conversations.

Conflicts and solution strategies in the curriculum updating process

There was little resistance and negative feedback on the reform and the new educational contents, as people were aware of the urgency of these changes. In addition, all actors with any kind of relationship to “Dental Technician EFZ” occupation were continuously informed about the process and the new developments so that no surprises occurred in the end. The main issue of conflict in the revision of the curriculum was along the lines manual vs. digital work and training. Digitalization posed challenges, above all to laboratories that were still working purely manually. As a strategy to resolve this conflict, a certain flexibility in training was therefore granted: For example, training laboratories are not required to possess a scanner of their own but must only guarantee that their apprentices have access to scanner training, e.g., *within a host company training network*. In addition, the number of days in inter-company training courses were increased from 20 to 33 days so that apprentices have additional time to acquire practical skills in these new digital methods, to ask questions and to improve their skills. This increase in the number of days also offers enough training time to acquire sufficient digital experience for those apprentices who have fewer opportunities to practice digital skills in their manually equipped host laboratories. Another way to resolve a conflict was that the new curricula remained open about which CAD program should be used. Instead it states that apprentices are trained in three different CAD programs in the inter-company training courses. How successful the far-reaching changes regarding the firm, the inter-company training courses and the vocational schools have been, remains to be seen, as the first cohort of apprentices training under the updated curriculum did not start until the summer of 2018. However, the Swiss Dental Laboratories association already expects that the occupation of “Dental technician EFZ” will in the future develop even further away from a manual craft and that digital elements will become ever more important. Furthermore, production in Switzerland will decline in importance, while service and temporal flexibility will become increasingly important in the future. This development thus poses the challenges for the next updating round of the “Dental Technician EFZ” curriculum.

[a] See http://www.vzls.ch/.

Essential information comes from an interview that took place on 16.10.2018 at the premises of Swiss Dental Laboratories in Bern with Christian Hodler, General Secretary, and Nadine Sieber, staff member of the General Secretariat and project manager of the revision of the VET occupation “Dental Technician EFZ”. Supplementary information comes from the association's internal documentation, which was made available to us confidentially for our case study.

[b] See https://www.gate.ezv.admin.ch/swissimpex/.

[c] The main actors of all learning locations were surveyed: the VPET trainers of the firms, the vocational teachers of the inter-company training courses and the vocational schools (the response rate was 41 percent, i.e., 43 of 104 distributed questionnaires were completed and returned), and the apprentices in the last (the 4th) apprenticeship year of school in the German-speaking area of Switzerland (the response rate was 100 percent; no feedback was obtained from the French-speaking area of Switzerland) (see “Final Report on the 5-year assessment of Apprenticeship Training Dental Technician”).

In addition, the systematic curriculum updating process has an innovation-driving effect in companies that are not yet at the innovation frontier. This innovation effect is based on the fact that when updating curricula, information is systematically collected from innovative companies in the sector and at the innovation frontier. The new competence requirements determined by this process are then incorporated into the curricula (cf. the example of the diffusion of digitalization among “Dental Technicians EFZ” in Box 3). The information on future developments and competence requirements is then further diffused via the curricula that are used by a broad range of companies, i.e., also those who have not yet been on the innovation frontier but are participating in apprenticeship training. This innovation effect is first investigated by Backes-Gellner (1996). She examines the developments after the reform and update of the metal-working occupations in Germany, in which CNC was introduced into the VET curricula for the first time in the mid-1980s. She shows in a country comparison of matched companies of the manufacturing sector that CNC machines have spread faster in German companies; she also shows that the share of shop floor programming (as opposed to back-office programming) is larger and that thereby the flexibility is higher and the downtimes in German companies are significantly shorter than under otherwise identical conditions in English or French companies (Backes-Gellner, 1996: 278 and following). Backes-Gellner & Rupietta (2018) later examine the relationship between the participation of companies in training apprentices and their product or process innovations more generally. They also find positive effects, which they theoretically explain with the systematic curriculum updating process (cf. detailed Chapter 3).

In conclusion, the Swiss VPET system (based on its legal foundations and the accompanying institutions, actors and processes) constitutes an excellent basis for the implementation and promotion of innovations in Swiss companies. It also promotes the diffusion of innovative technologies and processes across the broad spectrum of companies that are not yet at the innovation frontier.

2.3 Permeability in the education system and adaptability of VET graduates under new qualification requirements

The ever-changing work requirements associated with innovation (e.g., in the course of increasing digitalization) are changing occupational tasks and call for a continuous development of skills. The extent to which graduates of basic vocational training are able to acquire new and/or higher-level qualifications depends first, on the initial bundle of competences they acquire, for example, with a VET degree (see previous chapter) and second, and more importantly, on the opportunities for continuing education and training and for higher-level qualifications, i.e., on the permeability of the education system.[37] As will be shown below, VET graduates in Switzerland are in fact very flexible in terms of career development; they are mobile both horizontally and vertically as well as across the two strands of the Swiss education system (VPET and general academic education). This mobility and adaptability provides a solid basis for the innovative capacity of the Swiss economy.

Horizontal occupational mobility

Graduates of one of the approximately 230 VET programs have the opportunity to further develop horizontally, i.e., at the upper secondary level, within Vocational Education and Training (for further details, see Chapter 4).[38] Depending on the canton or occupation, students entering their second VET program can take the regular or a shortened version of that second VET program. A similar approach also applies to adults who have not previously participated in a VET program. The VET Act also permits direct admission to the examination procedure (provided that the requirements for admission and sufficient work experience are met) as well as the validation of occupational competences without passing a final examination (see Giger, 2016; State Secretariat for Education, Research and Innovation, 2014a).[39] Recent studies have shown that adults make good use of the opportunities to participate in a first or a second VET program.

Schmid et al. (2017) present descriptive statistics on adults (from the age of 24) who have completed an initial or a second VET program. In 2015, more than 6,000 people completed such a program, an increase of over 28 percent since 2012 (Schmid et al., 2017: 32; see also Tsandev et al., 2017): 43 percent acquired their degree through validation of competences, 27 percent through regular VET programs, 20 percent through shortened VET programs, and 10 percent through direct admission to the final examination. The authors also provide for the first time insights into how many adults acquired a second degree, i.e., had already completed a formal qualification at least at the upper secondary level. The share amounts to 58 percent (Schmid et al., 2017: 78).

That such adult participation in VET programs is also attractive to companies is shown by the case study *maxon* (see Box 4).

Further insights into horizontal (and vertical) mobility are now also provided by the Federal Statistical Office (FSO) as part of the program "Longitudinal analyses in the education sector" (LABB).[40] For the cohort that graduated from the upper secondary level in 2012, on the one hand, there are highly permeable boundaries between employment and education until 2015. On the other hand, and as a result, there are very diverse educational and employment pathways after their graduation at the upper secondary level.[41] Almost one-third of VET graduates (three- or four-year VET programs) obtained a further qualification or were still in training at the end of 2015. However, the share of individuals who underwent a second education in another VET program was small for this observation period (4 percent) (Federal Statistical Office, 2018b: 19).[42]

Labor market data can also be used to determine whether and to what extent employees switch from jobs in their originally learned occupation to jobs in another occupation during the course of their employment career. Such switches can take place as part of further training/higher-level qualification programs or can be based on the fact that sufficient competences and skills can be transferred from the originally learned occupation to another (cf. also Chapter 4.1).

Several studies provide empirical evidence on this form of occupational mobility, with concrete figures varying between data sets due to measurement differences and different observation periods. Müller & Schweri (2015) use TREE (Transition from Education to Employment) data to show that one year after completing their VET program, 7 percent of graduates have changed occupations. Eggenberger et al.

[37] Since more than two-thirds of young people in Switzerland follow the vocational pathway at the upper secondary level after completing compulsory schooling, these (vocational) educational upgrading options are important.

[38] The extent to which graduates of VET (without a second education) are mobile across companies and across occupations and how this affects labor market effects, such as wages, is addressed in Chapter 4.

[39] Another possibility is the validation of non-formal training achievements (see State Secretariat for Education, Research and Innovation, 2014a).

[40] Owing to the newly introduced personal identifier AHVN13, individual data from various education and labor market statistics can be linked and transitions in the education system—among other issues—can therefore be analyzed (Federal Statistical Office, 2018a).

[41] The observation period of 42 months refers to the period since graduation (generally summer 2012) and the date of the last (currently) available data (end 2015) (Swiss Federal Statistical Office, 2018b: 5).

[42] The vast majority of the cohort undertook continuing education at the tertiary level. In this context, however, the authors point out that the transition phase after upper secondary education lasts several years. For example, the proportion of people who completed a VET diploma (EFZ) and who later took up continuing training increased with increasing time after the completion of their VET degree: while the proportion in the first six months after graduation was 17 percent, it was 23 percent 42 months after graduation (Federal Statistical Office, 2018b: 5).

(2018) use the data set SESAM (Social Protection and Labor Market) of the FSO and find that approximately 14 percent of all employees with a VET degree have changed their profession at least once. Schellenberg et al. (2015) analyze a sample of 432 young people and find that in the first half of their working life (19 to 36 years of age), almost 50 percent of them changed their occupational field at least once.[43]

In summary, there are clear empirical indications of widespread horizontal occupational mobility in Switzerland.

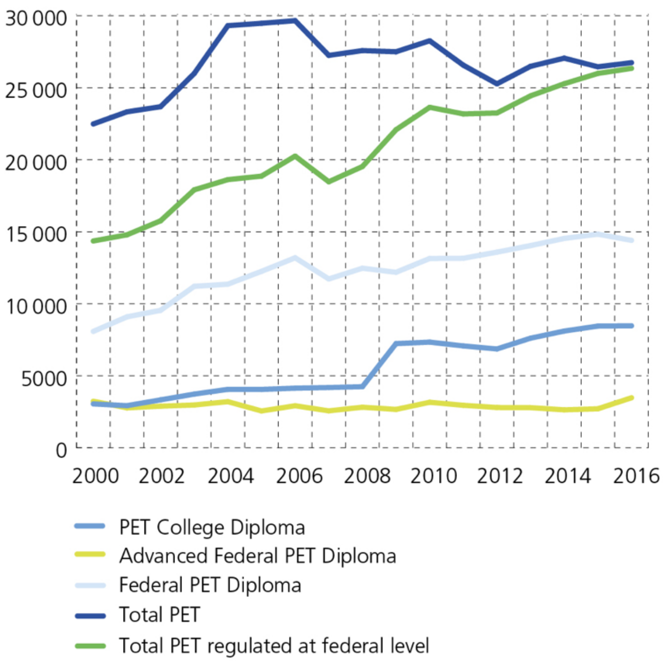
Vertical occupational mobility

Switzerland's VPET system also offers a wide range of vertical occupational mobility, or educational upgrading to higher-level qualifications, which differ in terms of professional orientation and scientific aspiration (see introduction). The number of PET degrees, i.e., those taking the PET examinations, and the number of UAS graduates was just under 27,000 in 2016 and has remained relatively constant over the last ten years (cf. Figure 3, line “Total PET”).[44] An increase was recorded particularly in the newly created PET programs as well as in the PET diploma examinations.

Another possibility of vertical mobility is offered through the degree programs at the UASs, which were established in the late 1990s. These brought new career opportunities and training in applied research for VET graduates. The number of graduates has risen steadily since the UASs were founded and has risen particularly sharply in recent years. In 2016, the number of bachelor's degrees was 12,866.[45] This means that UASs now train almost as many graduates as the UNIs and FITs together.[46]

In summary, the descriptive statistics show that the vertical mobility opportunities offered through PET and UASs are well exploited, thus laying a further foundation for the innovative capacity of the Swiss economy.

Figure 3: Annual number of PET degrees



Source: Illustration based on data from the FSO—Statistics on educational attainment

Mixed educational paths

The Swiss education system also offers a high degree of permeability between the VPET and the academic education strands. VET graduates with a vocational baccalaureate, for example, have access to a UNI or a FIT via a so-called *Passerelle*[47], a supplementary examination that grants access to all universities and fields. Whereas in 2005, only 3.5 percent of vocational baccalaureates passed this examination, by 2017, the figure had risen to 7 percent.[48] Empirical studies show that “mixed educational paths,” i.e., changes between the two parts of

[43] They distinguish among six fields: 1) craft and technical; 2) investigative and research; 3) artistic and creative; 4) educational and nursing; 5) managerial and sales; and 6) regulating and administrative occupations.

[44] Due to recent reforms, such as the creation of PET colleges, the number of degrees regulated by the federal government has increased over time. Therefore, to avoid distortions, PET qualifications not regulated by the federal government are also represented.

[45] Bachelor's degrees from universities of teacher education are not taken into account. To ensure that individuals are not counted multiple times, diplomas are counted only for the period before the Bologna reform, and bachelor's degrees (and not master's degrees) are counted only for the period after the Bologna reform.

[46] In 2016, the number of bachelor's degrees at UNIs and FITs amounted to 14,319 (BFS, SHIS—Students and degrees at Swiss universities, 2017). Not included in these statistics are distributions between subjects.

[47] The “Passerelle” is a pathway from vocational baccalaureate to academic university. It is a supplementary examination for vocational baccalaureate graduates that is offered by the Swiss Baccalaureate Commission and organized by the State Secretariat for Education, Research and Innovation. Together with a vocational baccalaureate, the supplementary examination grants access to all Swiss universities and all fields of study. The type of preparation for the supplementary examination can be freely chosen by the individual. The preparation can be autodidactic or through a one-year course offered by private or public schools.

[48] In 2016, 14,396 individuals completed a vocational baccalaureate (Berufsmaturität), 7,325 while undergoing their VET (in parallel) and 7,071 after undergoing their VET (BFS—Survey on Educational Qualifications - SBA). The proportion of vocational baccalaureate graduates up to the age of 25 was thus 15.4 percent in 2016, and the proportion of general baccalaureate graduates (Matura) from grammar schools was 21.2 percent (BFS—Längsschnittanalysen im Bildungsbereich (LABB)). Almost 60 percent of individuals with a vocational baccalaureate enter a UAS immediately; a further 20 percent enter a UAS after one year, and more than 15 percent do so two or more years after completing their vocational baccalaureate. Among individuals with a general baccalaureate (gymnasiale Matura), 40 percent attend a university directly after graduating, a further 30 percent one year later and about 5 percent after two or more years (BFS—Studierende und Abschluss der Hochschulen, SBA). The number of vocational baccalaureate graduates (Berufsmaturität) rose from 10,621 in 2006 to 14,320 in 2017 (Federal Statistical Office, Statistics of Educational Qualifications SBA, 2018). With an increase in Passerelle examinations from 3.5 percent in 2005 to 7 percent in 2017, the Passerelle examinations show an above-average increase.

the Swiss education system, are comparatively frequent and that, compared to a purely academic or purely vocational educational path, they even show higher returns (Backes-Gellner & Tuor, 2010b; Pfister et al., 2017; Swiss Coordination Centre for Educational Research, 2014).

> There are very few empirical studies on "mixed educational paths."[49] Backes-Gellner & Tuor (2010b) use data from the Swiss Labor Force Survey to investigate which pathways the Swiss labor force has followed to complete tertiary education degrees. They show that almost 15 percent of individuals with tertiary academic degrees started their educational careers with a VET program and that approximately 12 percent of graduates with a tertiary PET degree started their educational careers in a general academic school (Gymnasium) where they acquired a Matura (the general university entrance requirement). Similarly, Pfister et al. (2017) find, based on data from the microcensus "Education and Training 2011," that approximately 23 percent of individuals with tertiary degrees followed a mixed educational pathway, i.e., changed from the vocational to the academic strand or vice versa. These studies also show that mixed educational pathways in comparison to purely vocational or purely academic educational careers have the same or even higher returns. Such mixed pathways therefore do not constitute a detour but rather a multiple qualification pathway that is in high demand and is rewarded on the labor market (cf. also Swiss Coordination Centre for Educational Research, 2014).

In summary, from a systemic point of view, the Swiss education system has incorporated a high degree of permeability. As a result, the working population in Switzerland has many and diverse opportunities for lifelong development, which in turn is an essential prerequisite for the innovative capacity of the Swiss economy. Descriptive empirical findings also show that horizontal and vertical possibilities for further developments are actually used by individuals. This indicates that there are sufficient incentives for individuals and for companies to take advantage of this permeability. How further training and higher-level qualifications affect company productivity and innovation is discussed in more detail in Chapter 3; how they affect the labor market careers of individuals is examined in Chapter 4.

2.4 The role of the Organizations of the World of Work (OdAs) in the innovative capacity of the VPET system in Switzerland

The Organizations of the World of Work (OdAs), and among them in particular the occupational and sectoral associations, are central to the functioning and innovative capacity of the VPET system. OdAs not only develop new occupations or revise existing ones but also make a significant contribution to quality assurance in VPET and to the pooling and dissemination of innovation knowledge. In essence, their influence results from six different roles.

- First, OdAs play a leading role in defining the content of VET programs. They are therefore decisive for the determination of current and future relevant qualifications (cf. Chapter 2.2).[50]
- Second, in the process of curriculum development, OdAs represent the interests of all the companies they represent. In the event of conflicting interests, they must ensure an adequate balance of interests. On the one hand, they must ensure that the occupations they define are as broad and future-oriented as possible, and on the other hand, they must ensure that a sufficient number of companies participate in the training of young people.[51] This depends to a large extent on the training requirements laid down in the VET curricula, as these determine the costs incurred by the companies and thus the advantageousness of the cost-benefit ratio and the willingness to train (Wolter & Ryan, 2011). The inclusion of the interests of different companies in the process of reforming VET curricula is a mechanism for ensuring that companies will also participate broadly in the VET system in the longer term (Caves & Renold, 2016).[52]
- Third, OdAs are a link to local employers. They can motivate companies (large and small, on the innovation frontier or far from it) to participate in VET, and they can provide support when they train VET students.
- Fourth, OdAs play an important role in the quality assurance of VET. They are significantly involved not only in the definition of the final examinations (the Lehrabschlussprüfung (LAP), i.e., the practical part of the examination) but also in the implementation of the examinations (e.g., by providing examination experts).

[49] A systematic empirical analysis of all permeability options between the academic and the vocational educational sector (e.g., the shortened VET programs for graduates from grammar schools) and from the vocational to the academic sector is thus far lacking.

[50] Wolter & Ryan (2011) underline the importance of employers' associations—i.e., OdAs and professional associations—in defining the content of VET curricula. Zbinden (2010) describes in detail how the process of defining the content of VET programs takes place and what role OdAs play in this process.

[51] In this context, a challenge is also posed by economic, linguistic and cultural differences between Switzerland's language regions and the resulting potential conflicts (Zbinden, 2010).

[52] Caves & Renold (2016) also show, by examining eight international reforms aimed at introducing a VET system in the US, Asia and Europe, that reform cases in which companies were heavily involved (i.e., in which they participated in the cyclical reform process of the VET system) are more advanced than those in which companies were not.

Quality assurance is in turn essential for the attractiveness of VET to young people and for the long-term employability of graduates.

- Fifth, OdAs run inter-company training courses and training centers, which are particularly important for the diffusion of the innovative skill components of new or revised VET programs.
- Sixth, OdAs are also providers of PET programs, which are one form of lifelong learning in Switzerland.

How the practice of these roles influences the innovative capacity of the VPET system and its graduates is explained in more detail below. For concrete case studies, see Box 2 and Box 3 in Chapter 2.2.

Definition of sustainable contents of basic vocational training within the framework of a regular curriculum update

The OdAs together with the federal government and the cantons take the lead in the definition of educational content, i.e., in the reform process of VET ordinances and curricula. The OdAs are responsible for operational project management and define educational content; they essentially determine the content of the VET programs, the qualification profiles and the VET curricula.[53] To fulfill these tasks, there are well-defined processes that can be summarized as follows (for concrete examples, see Box 2 and Box 3 in Chapter 2.2).

The basis for the occupational competences described in the VET curricula and for the ordinance and qualification profile of a VET program is an activity and occupational development analysis.

In the activity analysis, the OdAs first create a description of all occupational activities, the so-called activity profile. This activity profile should reflect the occupation-related thinking of good professionals in that particular occupation. It usually contains five to ten typical areas of activity and two to ten typical concrete activities of professionals per area of activity.

The occupational development analysis first outlines the range of possible occupational developments as well as the current strengths and weaknesses of that particular occupation. Second, it shows possible societal and market developments, and the resulting consequences for companies, for graduates of that particular VET program and VPET in general. On the basis of the occupational development analysis, the questions and problem areas of the occupation are explored. On this basis, concrete measures are specified to ensure that a new VET program is oriented towards the future.

The results of these two analyses then flow into the formulation of the VET curriculum, i.e., into the elaboration and specification of the occupational competences, lecture timetables, inter-company training courses, examination procedures, occupation descriptions and qualification profiles.[54]

The role of the OdAs with regard to the definition of future-oriented and thus innovation-promoting VPET content is therefore central for the creation of innovation. Furthermore, systematic curriculum updating has a positive effect on the diffusion of innovation knowledge (cf. Chapter 2.4). OdAs, and the companies and experts that are involved in the OdAs therefore play an important role in the relationship between the VPET system and the innovative capacity of the Swiss economy.[55]

Representation of company interests and balancing of interests

At the same time, the training requirements of the occupations laid down in the curricula have consequences, albeit indirect, for the training decisions of companies. The reason is that the training requirements of the occupation determine the costs incurred by companies that train an apprentice in that occupation. For the majority of training companies, VET in Switzerland is currently associated with a net benefit; i.e., the costs are lower than the benefits. This means that the majority of training companies currently generate a (small) profit during the training period since the apprentices can be utilized productively in the work process, which is sufficient to cover the costs (Wolter & Ryan, 2011).[56] The OdAs must take this incentive situation into account when defining training curricula, and they must ensure an adequate balance of interests between different types of companies.[57]

Further differences of interest arise because the companies are located closer to or further from the innovation frontier and as a result have a more or less strong interest in innovative training content. The more the interest in innovative training content dominates, the more it promotes the innovative capacity of the sector and the Swiss economy as a whole, but the more it can also jeopardize the willingness of companies to provide training across the board.

The inclusion of different interests via the OdAs is therefore also a mechanism to ensure the broad participation of the companies

[53] When developing occupational training curricula, the OdAs are methodologically and pedagogically assisted by vocational experts (e.g., from the SFIVET, cf. Zbinden, 2010).

[54] A direct connection to occupational activities is central in all these steps. A lack of connection, i.e., too much abstraction and generalization, is, according to Zbinden (2010), a possible stumbling block to the success of a reform.

[55] Their participation and their position in this reform process also promote confidence among the companies, which in turn are more willing to share important occupational content (Culpepper, 2003; Wolter & Ryan, 2011).

[56] See, for example, the cost-benefit studies by Strupler & Wolter (2012), Dionisius et al. (2009), Mühlemann et al. (2010), Mühlemann & Wolter (2014), Mühlemann et al. (2007a).

[57] In this context, economic, linguistic and cultural differences between the linguistic regions of Switzerland and the conflicts that may arise from them also pose a challenge. In the curriculum updating process, such differences can result, for example, from (well-founded) regional peculiarities (Zbinden, 2010).

in the long term (Caves & Renold, 2016). Only if the interests of different companies are adequately taken into account in the reform of VET curricula and if a sensible balance between any conflicting interests is found, it can be ensured that a sufficiently large number of companies actually offer training places. The case studies in Box 2 and Box 3 provide concrete examples of diverging interests in innovative training content and examples of potential ways to reconcile interests.

To strengthen Switzerland's capacity for innovation, it is crucial that innovative training content is implemented as early and as comprehensively as possible in reforms of VET training curricula. Making such changes possible is an important contribution of the OdAs to innovation.

Link to local employers

Another important role of OdAs, according to Wolter & Ryan (2011), is their proximity and connection to local employers. This allows them to mobilize employers if necessary and offer high-quality training places. However, there is also the danger of cartel formation in the coordination of operational interests (Wolter & Ryan, 2011). Another source of conflict is when small and medium-sized enterprises and large companies with different interests and strategies in VET are unequally represented in OdAs, in which case no adequate balancing of interests can be achieved (Wolter & Ryan, 2011). These problems must therefore be kept under control so that the influence of the OdAs can continue to develop its positive effects.

Quality assurance of basic vocational training

Ensuring the quality of training is another important element for a high-quality VPET system that also promotes innovation (BBG, Art. 8). This is particularly the case since the involvement of apprentices in the productive work process and the resulting net benefit for companies also entail the danger of using apprentices as cheap and unskilled workers at the expense of the quality of training (Wolter & Ryan, 2011). Statutory minimum standards for training quality and the monitoring of compliance with the standards can and must therefore counteract this risk.[58] In Switzerland, quality standards are essentially set by the federal government in VET ordinances and VET curricula. The cantons are responsible for verifying compliance with these standards (and with other labor law regulations). The *Qualification Procedure*, in which the vocational competences of apprentices are examined, evaluated and validated at the end of the apprenticeship is also subject to the legal standards and is an integral part of the VET ordinances and the VET curricula (Zbinden, 2010). While the cantons are responsible for the organization, implementation and monitoring of this procedure, the OdAs provide the examination experts. This procedure gives VET graduates a legally protected job title that is recognized throughout Switzerland. This is a credible sign of quality on the labor market, above all owing to the participation of OdAs (Wolter & Ryan, 2011).[59] The completion of a VET program thus gives graduates broad access to the external labor market and in the longer term provides them with the basis to adapt their skills in the event of changes in their training occupation or in related occupations.[60] In addition, a VET degree enables access to further education, e.g., at the tertiary level. The interaction between OdAs and the state for VET quality assurance therefore lays the foundation for the supply of a highly skilled VET workforce and for VET graduates' long-term adaptability in dynamic environments.

Owners of inter-company training courses and training centers

The OdAs are also often owners of training centers where inter-company training courses are offered.[61] These inter-company training courses represent a third learning location in addition to the vocational school and the practical training in companies. Inter-company training courses serve to impart basic skills and, above all, innovative content that is not yet generally available in companies. Inter-company training courses include multiple visits over a few days or weeks during which apprentices have support and time to combine theory and practice. As a consequence of the specialization of some companies, inter-company training courses often also fill learning gaps.[62] In some cases, these training centers also function as competence centers for the sector, as they produce expertise and test procedures and carry out R&D. Therefore, they also play an important role in the development and diffusion of innovations.[63]

[58] In addition to these legal requirements, companies also have their own incentives to offer high-quality training to their apprentices (Backes-Gellner & Tuor, 2010a; Wolter & Ryan, 2011). On the one hand, apprentices can be employed as competent skilled workers in the company after completing their training, thus ensuring that the demand for skilled workers is met. On the other hand, low training quality can have negative reputational effects on the apprenticeship market and the labor market, which has a strong negative impact on the future applicant pool of companies (cf. Backes-Gellner & Tuor, 2010a).

[59] For three- to four-year VET programs, it is the VET diploma (EFZ); for two-year basic training, it is the Federal Certificate of VET (EBA).

[60] Since VET programs teach typical vocational skills, the acquired skills, knowledge and abilities can be transferred between companies. The extent to which VET is actually transferable between companies and occupations is examined in Chapter 4.

[61] The Federal VPET Act prescribes that the cantons—with the participation of the OdAs—are responsible for a sufficient number of inter-company training courses. The infrastructure of the training centers for inter-company training courses is often also used for PET (Wettstein et al., 2014).

[62] What weighting should be given to the different tasks of the inter-company training courses is the subject of important discussions among the responsible actors.

[63] Backes-Gellner and Rupietta (2018) argue in their study, in which they analyze the role of the VPET system with regard to innovation diffusion, that the inter-company training courses, which impart novel content at the innovation frontier, especially contribute to the innovation effect.

Providers of Professional Education and Training

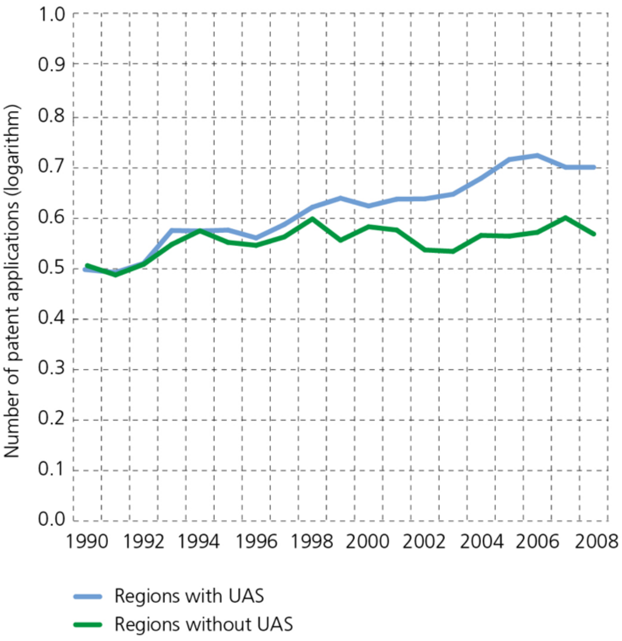
OdAs also play an important role in PET and thus in lifelong learning for VET graduates. They are involved in both shaping and implementing the approximately 400 courses of PET colleges, the 240 Federal PET Diploma Examinations and the 170 advanced Federal PET Diploma Examinations (for further details on PET, cf. Swiss Coordination Office for Educational Research, 2018: 272–283). In doing so, OdAs also make a significant contribution to increasing the quality and adaptability of the skill mix available in the labor market and in turn to the innovative capacity of VPET.[64]

2.5 Vocational-academic skill mix and innovation: Empirical findings

The Swiss education system offers a wide range of formal vocational and academic qualifications both at the upper secondary level and at the tertiary level. The Swiss labor market is thus made up of people with very diverse educational backgrounds and a broad set of different skills. This contributes to the fact that Switzerland's innovation and production model[65] can build on a combination of well-trained university graduates on the one hand and highly qualified skilled workers from the VET system on the other hand (the same applies to Germany; cf. Backes-Gellner, 2017). This allows a combination of diverse, high-quality knowledge sources that can be used not only for high-quality production but also for innovation. [66] A few recent studies in Switzerland have empirically examined the effects of this skill mix on innovation.

For example, Bolli et al. (2017) show that the blending of workers with vocational and academic education at the tertiary level promotes innovation (see also Chapter 3 for more details).[67] In addition, several recent studies have examined the influence of the skill mix typical of UASs (solid VET and applied research competences). Pfister et al. (2018) investigate the effect of the establishment of UASs (and thus the appearance of new types of bachelor's degree graduates) on regional patent activities (as a key innovation indicator for MINT orientations) (cf. for details Chapters 0 and 4.2). The results show that the establishment of UASs has significantly increased the quantity of patents in the affected regions. This can be seen graphically from the end of the 1990s onwards in the stronger increase in patenting in regions with UASs compared to regions without UASs (cf. Figure 4). Similar developments can also be seen for the quality of patents; different quality indicators also increased significantly in the period under review (cf. Pfister et al., 2018).

Figure 4: Patent activity (1990 to 2008) of regions with and without the establishment of Universities of Applied Sciences (UASs)



Source: Calculations by Pfister (2017) based on EPO Worldwide Patent Statistical Database, April 2013 version (cf. Pfister et al., 2018).

Lehnert et al. (2017) find in a subsequent study that the establishment of UASs actually led to an increase in R&D personnel in companies in the treated regions. Newly available UAS graduates seem to have been used not as a cheap substitute for university graduates as R&D personnel but rather as a complement to university graduates. The combination of sound occupational skills with application-oriented research knowledge brought by UAS graduates builds an ideal bridge between the requirements of the production process and the challenges of R&D processes. [68]

[64] At the same time, they offer VET graduates attractive opportunities for further training at the tertiary level and thus make a general contribution to the attractiveness of VET, especially to young people with career potential. The empirical findings presented in Chapter 4 even show that the individual rates of return for PET degrees are equivalent to those for academic university degrees.

[65] This applies similarly to Germany (see Backes-Gellner, 2017).

[66] For Australia, Toner et al. (2004) and Toner (2010), emphasize—relying on descriptive statistics and case studies—the importance of VET skills for product and process innovation, for improving productivity and for the diffusion and the creation of new knowledge. They argue that a high ratio of workers with academic qualifications is not a good predictor for innovation, thereby alluding to the complementarity between academic and vocational skills. Based on their study from Australia, they explain why VET may have a positive effect on innovation. They point to the potential importance of skilled production, trade and technician occupations in technical change, given their central role in designing, installing, adapting, operating and maintaining capital equipment, software and consumer goods (Toner et al. 2004). However, in general the innovation literature has, over the last three decades, largely ignored the role of the direct production workforce in innovation: There is surprisingly little literature within the "innovation studies" tradition with an explicit focus on skills and skills formation, but the importance of skills and skill formation is implicit throughout the literature. (Tether et al. 2005: 73).

[67] Further details on the study by Bolli et al. (2017) can be found in Chapter 4.

[68] The fact that employees with VET degrees and employees with a tertiary degree complement each other excellently is also demonstrated by a study by Backes-

For example, an important factor in the exchange between production and R&D is a common professional language that substantially eases communication and thus promotes mutual fertilization in the innovation process. Well-trained VET graduates, due to their broad education and training (practical and theoretical), speak a common professional language with the development engineers. Furthermore, due to the usual spatial proximity, there are often unscheduled encounters, which in turn promote knowledge exchanges. The innovation process therefore does not have to take place in sequential steps, but can rather take place in parallel steps (Backes-Gellner, 2017).

Schultheiss et al. (2018) investigate whether the establishment of UASs also led to changed task structures in companies. Specifically, they analyze to what extent there were more R&D-related task profiles in the job advertisements of the affected companies after the establishment of UASs. They find that after the establishment of UASs, companies looked not only for UAS graduates for R&D tasks but at the same time looked for an increasing number of VET graduates for jobs with R&D-related main tasks. VET graduates are therefore not displaced by UAS graduates. Instead, an overall higher R&D intensity is induced in the affected companies, and VET graduates are increasingly involved in these new R&D activities.

Overall, the results point to strong cooperation between VET graduates and UAS graduates as bridge builders to graduates of UNIs for R&D tasks. UASs thus contribute their characteristic skill mix to the above-mentioned increase of regional innovation activities (measured by patent quantity and quality).[69] This finding is also confirmed by the case studies of innovative companies documented in this chapter (cf. Box 4, *maxon*, Box 5, *Novartis*, and Box 6, *Bühler Group AG*).

The case studies at *maxon* and *Bühler Group AG*, for example, show that UAS graduates are a central pillar of innovative performance because, among other things, they bridge the gap between theory and practice. The case study *Novartis* shows that VET graduates as part of the Hit Generation Sciences Group make important contributions to innovation. Further concrete examples can be found in the case studies presented in the chapter “Knowledge and Technology Transfer of Science Organizations in Switzerland” (Research and Innovation in Switzerland—Report 2020). It provides the example of *KWC Ranke Water Systems AG* for which, cooperation with UASs is mentioned as a prerequisite for the success of a digitalization project in the automation of grinding processes. The success is based on a large number of student projects of the cooperating UASs in which partial aspects of the solution were developed. The *IRsweep* case study also shows that, in addition to claiming global excellence in cutting-edge research, the company was essentially confronted with far more practical issues, such as the measurement of trace gases and the development of precise measuring instruments. The “combination of basic and applied research as well as the combination of complementary expertise and know-how on chip-based lasers and spectrometers ultimately formed the technical and knowledge basis for the company” (see chapter “Knowledge and Technology Transfer of Science Organizations in Switzerland” in Research and Innovation in Switzerland—Report 2020).

In summary, the empirical studies relating to Switzerland show that the well-balanced skill mix of vocational and academic education and training represents an important dimension of the innovation system in Switzerland. VET graduates contribute solid practical occupational competences; UAS graduates, through their combination of solid practical occupational competences with applied research competences, and a common professional language, build a bridge between the requirements of the production process and the challenges of the R&D process;[70] and FIT/UNI graduates guarantee a connection to the international research frontier. The broad skill mix and the combination of different types of knowledge and conceptually different sources of knowledge thus have a positive effect on innovation in companies[71] and affected regions. This is essential for Switzerland's leading international innovation position.[72]

Conversely, the results also indicate that the results of empirical studies from countries with purely (or predominantly) academic education (such as Anglo-Saxon countries) are not transferable, or at best are transferable only to a very limited extent, to Switzerland (or other countries with a strong VET sector). Educational policy conclusions therefore must also differ. In contrast to countries with dominant academic education, countries with a pronounced VPET sector must focus not on maximizing the number of graduates from academic programs[73] but rather on an innovation-enhancing mix of skills from vocational, academic and mixed education pathways.

Gellner et al. (2017) that examines how the productivity or wages of employees with tertiary degrees are related to the number of VET graduates employed within a company. It finds that—all else being equal—wages are statistically significantly higher if more VET graduates are employed (albeit with declining growth).

[69] UASs also increase the attractiveness of a VET path for young adolescents, as they open an attractive career path for VET graduates (cf. Chapter 4).

[70] For details, see Backes-Gellner (2017).

[71] The positive effects can also be related to certain company human resources management measures, organizational structures or corporate strategies. This is examined in more detail in Chapter 0.

[72] Meuer et al. (2015) investigate to what extent the innovation-enhancing effects of VET depend on being embedded in a particular innovation system (with specific other characteristics). They identify five types of innovation systems for Switzerland. VET plays a positive role in almost all the systems but above all in the “knowledge internalization innovation” system. The latter system is generic in nature and therefore relevant to all sectors and regions of the Swiss economy.

[73] While for countries without VET, it can be a highly rational strategy to increase the number of students at colleges, the same cannot be concluded for countries with a well-functioning VET system. Countries without VET are combating a shortage of well-qualified middle-skilled workers with increasing numbers of college students, a shortage that does not even exist in this form in the latter systems (because a large number of VET graduates are trained with distinctive and future-oriented middle-skilled qualifications).

Box 4

Case study: *maxon*—Development of innovative top-quality products through a broad skill mix and close cooperation

maxon[a] has a globally leading position in the manufacture of high-quality drive components and systems—e.g., brushless and brushed DC motors—in the industrial, transportation, medical, aerospace and space and robotics sectors. In the ExoMars rover, for example, which will explore the surface of Mars beginning in 2020, over 50 drives from *maxon* are installed. In 2017, the firm generated sales of almost CHF 460 million, producing in Switzerland, Germany, Hungary and Korea. The headquarters of *maxon* is located in Sachseln, Central Switzerland, where almost half of the 2,500 employees work. Research and development also takes place primarily in Central Switzerland: Of the 200 employees working in R&D worldwide, more than 160 are located in Sachseln. At the headquarters, more than 50 apprentices are trained, mainly in the occupations of “Design Engineer EFZ”, “Polymechanic EFZ”, “Automation Engineer EFZ”, “Electronics Engineer EFZ” and “Information Technologist EFZ”. Three-quarters of these apprentices work in R&D or R&D-related positions.

Innovations are of crucial importance to *maxon*, as, given the high wage costs in Switzerland, the firm can survive in the market only by being a technological leader. On the one hand, innovations refer to standard products within the product families (e.g., motors, gears, controls, encoders) and the parameters within which the product functions (e.g., evaluation of different storage concepts or simulations of high-frequency electromagnetic fields). On the other hand, the company also generates innovations in the form of customer-specific applications in which standard products from the product families are combined and supplemented. Finding a solution therefore requires innovation and creativity: For example, a problem with a drive system can be solved in the engine, compensated for with the software, or addressed by different types of gears. Both types of innovation are equally important for the firm. Similarly, the processes of the two innovation types are similar, even if they start from a completely different basis. In addition, both innovation types and processes have one important thing in common: the importance of Vocational Education and Training for the generation of innovation.

The importance of Vocational and Professional Education and Training for the innovative performance of the firm

In *maxon*'s R&D, the proportion of academic graduates, i.e., employees with a general baccalaureate (Matura) and UNI or FIT degree, is small (approximately 10 percent). Approximately 90 percent of employees working in R&D have a vocational background. Approximately 20 percent of them have a VET degree as their highest degree; the vast majority, however, have additionally completed a PET program or a degree program at a UAS after completing their apprenticeship. This mix of educational backgrounds is deliberately chosen by the firm. While UNI or FIT graduates have a strong theoretical and mathematical background, graduates of UASs have a comparative advantage in the practical field. Graduates of PET colleges or of UASs, who have undergone an apprenticeship, represent a particularly important pillar for *maxon*. In addition to their supplementary research- and science-based education, their practical vocational skills acquired in apprenticeships are particularly important. Given their (educational) background, UAS engineers are not only aware of the pitfalls in manufacturing a product but also speak the same language as the vocational professionals, which ensures excellent communication between production and development. This creates synergistic effects in the collaboration between, for example, “Polymechanics EFZ” and mechanical engineers or “Automation Engineers EFZ” and electrical engineers. UAS graduates—and their collaboration with vocational professionals on the one hand and with FIT engineers on the other—therefore constitute an important bridge between theory and (professional) practice and substantially contribute to the innovative performance of *maxon*.

Learning “Polymechanic EFZ” apprentices
Photo: maxon

Innovation through teamwork and knowledge exchange

Innovation at *maxon* is created not by individuals but always by teams. The firm works exclusively on a project group basis; i.e., all tasks—regardless of whether they involve the creation of a new innovative product for the catalog or the development of a customer-specific and innovative application from existing catalog products—are pursued in project teams. The teams are deliberately staffed with mixed qualification types to incorporate the strengths of different educational careers into the solution of a task. *maxon* adheres to the premise that added value is created by combining different types of graduates and by combining a wide range of specialist areas. Project teams therefore typically consist not only of a project manager and employees from the development department—even if they make up approximately three-quarters of the team—but also of employees from the production, logistics, purchasing or quality assurance departments.

One example of particularly successful team performance was the development of a new precision motor for extreme conditions[b] such as temperatures up to 200°C or pressures up to 1,700 bar, such as those found in deep drilling technology. Specialists from development—i.e., the project manager and the employees in the predevelopment and development laboratory—were not the only ones involved in the technical solutions, calculations and concept development. Feedback from the “Design Engineer EFZ” who designed the components and from the “Polymechanic EFZ”, a VET graduate who manufactured the assembly tools, also contributed significantly to the innovation. The interdisciplinary composition of technical and educational backgrounds as well as their close interaction was therefore essential.

Collaboration is seen as an essential key to success. To ensure that interactions function well across all areas and hierarchical levels, competence-oriented collaboration is cultivated. Hierarchies play a minor role; competences and decision-making powers lie with the employees who are specialists in the particular area. For this reason, when selecting project managers, attention is paid not only to their professional expertise that is suitable for the project but also to their organizational, communicative and management skills. A good discussion culture between (and within) the different departments, which includes openness and mutual respect, is deliberately promoted and practiced.

The importance of continuing qualification and lifelong learning

For *maxon*, the further development of its employees is essential to ensure the firm's technological leadership in the market. The company therefore invests more than CHF 1 million annually in further training and education for its employees. For example, courses in collaboration, e.g., leadership without a supervisory function, are offered. Continuing education, e.g., at PET colleges or UASs, is also supported and promoted. More than half of the apprenticeship graduates thus continue their vocational education at the tertiary level; they often complete their studies parallel to their work, with part-time employment at the firm.

At the same time, apprentices are sensitized during their apprenticeship to the importance of further qualification that builds on a sound professional foundation. As the firm cannot train its apprentices in all areas as deeply as it actually needs to do during the specified VET program period of three to four years, the apprentices—in consultation with the VPET trainers—specialize in certain areas during their apprenticeship. For example, an “Automation Engineer EFZ” can specialize in programming PLCs, while others specialize in programming microprocessors. Later, they can and will continue to qualify in depth or breadth. The mutual awareness of constant further development also explains, among other things, the high proportion of further education and training after apprenticeship completion.

However, further qualification takes place not only formally, i.e., at the UASs or PET colleges, but also through job rotations within the company. Employees who, for example, work first in the workshop, then in the engineering department, and finally in the laboratory acquire valuable bundles of skills from which the firm's innovative capacity later benefits. Moreover, such job rotation disseminates knowledge within the firm. *maxon* is aware of this benefit, which is why the firm strongly promotes internal mobility. All vacancies, for example, are first advertised internally to continuously create opportunities for the further development of employees.

Learning “Automation Engineer EFZ” apprentices
Photo: maxon

The challenge of filling apprenticeship positions

In recruiting apprentices, *maxon* currently faces major challenges related to demographic trends, i.e., a decrease in the percentage of young people, which is reinforced by the simultaneous rise in the general baccalaureate (Matura) quota. In addition, mobility has increased among young people, who are currently more likely to also go to other cantons for education and training. The pool of potential applicants with the necessary requirements for VET programs has therefore shrunk considerably. Owing to its strong local roots, the attractiveness of the firm and the apprenticeship places it offers, as well as investments in the technical, pedagogical and didactic further training of VPET trainers, *maxon* can counteract this challenge and continues to achieve a high level of filled apprenticeship places.

maxon sees new potential to solve the shortage of VET workers in the vocational integration of adults who currently do not have an upper-secondary-level education degree. These are often migrants who have been living in Switzerland for 10 to 20 years and have become Swiss citizens but have not undergone any formal vocational or professional Qualification Procedures due to their migration history. *maxon* launched a pilot project in summer 2018 in which eight adults are being trained as ”Automation Fitters EFZ”. They are taught in a separate class at the vocational school. *maxon* regards a separate class as a prerequisite for a successful project: on the one hand, to reconcile education, job and family (e.g., with school sessions taught on Saturdays) and on the other hand, to be able to make better use of the richer (life and work) experience in class. Such adult qualification programs are regarded as a viable solution to the problem of skilled labor shortage and are also already highlighted in the VPET mission statement for 2030 that was developed in a VET-partnership process. The next important step is to develop concrete concepts for vocational schools curricula and for teachers at vocational schools to receive further training in additional competences so that they can specifically teach such adults.

To overcome the shortage of apprenticeship applicants due to rising baccalaureate quota and to still be able to fill vacant positions *maxon* considers as one possible solution to offer shortened apprenticeships to general baccalaureate graduates who—after a detour via a Gymnasium (general baccalaureate school)—want to enter the practical world in an enterprise.[c] For example, *maxon* recently (in 2018) signed apprenticeship contracts with two female general baccalaureate students for the two-year “Way-Up VET program” for “Automation Engineers EFZ”. In these shortened apprenticeships, in which qualifications acquired at the general baccalaureate school are recognized and supplemented by subject-specific theory and professional practice, the company sees an opportunity to—despite rising rates of general baccalaureate quotas—acquire and train a sufficient number of highly qualified skilled workers in the future.

Another threat to the current excellent qualification base and the necessary skill mix in the area of R&D is seen by *maxon* in the emerging education trends at UASs, i.e. universities with an original mandate for teaching and research in applied sciences. Those UASs, which—contrary to their original mandate—are moving towards academic universities in terms of their objectives, students and education, are losing their comparative advantage, namely, the combination of comprehensive practical and vocational skills with application-oriented research. There are already indications that graduates of UASs—who have not completed an apprenticeship but have obtained a general baccalaureate degree—neither have the sound practical professional background nor possess the theoretical depth taught at UNIs and FITs. Graduates with this lack of both professional practice and theoretical knowledge are difficult for the firm to employ as such, and the lack can also not be compensated for in the firm.

A further challenge for *maxon* is the future skills requirements of apprentices. Communication skills, teamwork and inter-cultural skills are becoming increasingly important. In addition, interconnected thinking has also gained in importance. A number of areas of conflict exist here that will have to be dealt with in a sensible way in the future. For the “Polymechanic EFZ”, for example, manual work is still indispensable, for example, to understand why a workpiece begins to vibrate in the lathe. However, programming has also become increasingly important and already amounts to one-quarter of the training. On the firm side, the basic content of the VET program is well structured, but the inclusion of even more innovative technologies, such as robotics for “Automation Engineers EFZ”, is desirable. To meet the additional requirements in general skills the compulsory school level, curriculum 21 is heading in the right direction; in Vocational Education and Training, however, efforts are still needed for interdisciplinary projects and self-directed learning. In the future, company-based and school-based curricula will also need to be appropriately coordinated. *maxon* still sees great potential for improvement particularly in the cooperation between different learning locations, i.e., the coordination of learning content among the various learning venues.

At the same time, the role of VPET trainers is changing and must be adapted to emerging developments. Currently, VPET trainers are increasingly challenged in their training activities by acting not only at the technical level but also to an increasing extent at pedagogical, didactic and interdisciplinary levels. *maxon* therefore cooperates with the University of Teacher Education Lucerne on a project that aims to answer the question of which competences VPET trainers need to be taught to improve the teaching of, for example, self-organized learning to apprentices. Maintaining the ability to innovate will depend on the success of such continuous further developments in Vocational Education and Training.

[a] See https://www.maxongroup.com.

Key information comes from an interview with Mr. Stefan Preier, Head of Human Resources, and Mr. Thomas Müller, Head of Vocational Education and Training, which took place on 25 October 2018 at the premises of *maxon* in Sachseln. Supplementary information comes from internal company documentation that was made available to us confidentially for our evaluations.

[b] *maxon* received the Innovation Award of the Central Swiss Chamber of Commerce for this engine in 2010.

[c] See https://www.find-your-future.ch/de/berufslehre/verkuerzte-lehre/way-up/.

3 Company level

Of all firms in Switzerland, companies conducting R&D and generating innovations account for a comparatively high percentage. The share is highest in the high-tech industry (over 47 percent report being active in R&D, and over 60 percent have generated an innovation), followed by the low-tech industry (22 and 40 percent, respectively), modern services (15 and 30 percent, respectively) and traditional services (8 and 31 percent, respectively) (cf. Wörter & Spescha, 2018: 10–23).[74] Small and medium-sized enterprises in comparable industries exhibit similar percentages, while the percentages of large firms are higher (Wörter & Spescha, 2018: 21–23).[75]

3.1 Participation of companies in apprenticeship training and demand for apprenticeship places

At the same time, companies are key actors in the VET system because they provide training places for apprentices and are responsible for the quantity and quality of the company-based part of dual VET (in the broader sense, they also belong to the OdAs (State Secretariat for Education, Research and Innovation, 2017a), cf. for details Chapter 2).

Participation of companies

The contribution of companies to the VET system is thus decisive for the innovative capacity and the innovation effect of VET. However, their participation in the VET system is voluntary (State Secretariat for Education, Research and Innovation, 2017a), meaning that cost-benefit considerations and other training incentives are essential for the participation of companies and thus the functioning of the Swiss VET system. Empirical cost-benefit analyses of the company-based part of VET in Swiss companies show that for the majority of companies providing dual VET, the benefits (which result from the use of trainees in productive work processes) outweigh the training costs (cf. Gehret et al., 2019).[76] This represents an important incentive for the provision of apprenticeship places in Switzerland's VET system.[77]

Availability of apprenticeship applicants

Whether a company trains apprentices also depends on the availability of suitable applicants, i.e.,—essentially—on the number of graduates from compulsory school that apply for an apprenticeship training. The number of applicants for apprenticeship training (and thus indirectly on the training activities of the firms) is influenced by the demographic development (i.e., the size of the various birth cohorts) and by the number of school places in baccalaureate schools (Gymnasium), i.e., the alternative to an apprenticeship. Empirical findings over the past 25 years have revealed clearly asymmetrical developments in Switzerland in this respect. While firms and baccalaureate schools have reacted with a similarly strong increase in the number of training/school places in times of growing cohorts of compulsory school graduates, in times of shrinking cohorts, they have reacted in markedly different ways. As Figure 5 shows, each additional compulsory school graduate led to approximately half an additional school place and half an additional apprenticeship training place (approximately +0.6 and +0.5 in Figure 5, left side) when the number of compulsory school graduates increased. This means that the additional demand was covered to roughly half and half by baccalaureate schools and firms. However, with shrinking compulsory school graduate

[74] R&D-conducting firms indicated that they are active in R&D during the observation period (2014–2016). Firms generating innovation created a product or process innovation in the same period. Organizational or marketing innovations are excluded from this indicator. The share of firms that generated organizational or marketing innovations between 2014 and 2016 is higher than the share of firms that generated product or process innovations in all industries and firm sizes, most significantly in traditional services firms. The percentage of firms with organizational or marketing innovations is 70 percent in high-tech industry, 65 percent in low-tech industry, 50 percent in modern services and 60 percent in traditional services (cf. Wörter & Spescha, 2018: 10–23).

High-tech industry, low-tech industry and modern and traditional services are classified by the authors using NOGA codes. The sectors pharmaceuticals, chemicals, electrical engineering, mechanical engineering, electronics and instruments, vehicles, watches and medical technology are part of the high-tech industry. The wood, textile and clothing, food, plastics, printing, paper, stones and soils, metal products, metal production, repair, energy, water and environment and other industries are grouped into the low-tech industry. Modern services include information technology, banking and insurance, telecommunications, media, technical and non-technical business services; traditional services include hospitality, logistics and transportation, wholesale and retail, personal services, real estate and rentals (see Words & Spescha, 2018: 16–18).

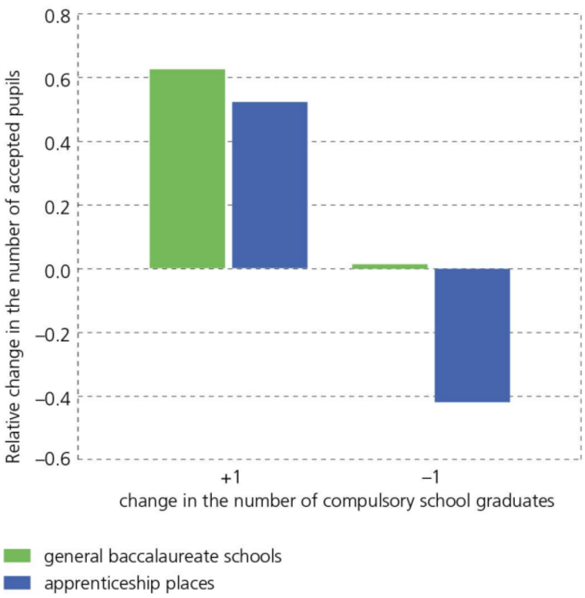
[75] Large firms tend to show above-average percentages but account for only a small proportion (1 percent) of the economy (Wörter & Spescha, 2018: 21–23).

[76] In contrast to Switzerland, the majority of companies in Germany incur net costs (Dionisius et al., 2009; Jansen et al., 2012; Pfeifer et al., 2010). In Germany, therefore, the longer-term benefit accruing after apprenticeship completion is more important for the training decision. This is achieved, for example, in the form of savings in recruitment costs for highly qualified skilled workers (Mühlemann et al., 2010; Mühlemann & Wolter, 2014). The differences in the company cost structures in the training of apprentices in Germany and Switzerland are related, among other things, to the flexibility of the labor market; the different relative wage levels of skilled workers in the lower, intermediate and upper qualification levels; and differences in the participation of apprentices in the productive work process in the company (cf. e.g. Dionisius et al., 2009).

[77] In addition to cost-benefit considerations, firms can of course also have other motivations to train apprentices. For example, training firms also have systematic advantages in recruiting skilled workers from the external labor market, as training apprentices is perceived as a quality signal on the external labor market (Backes-Gellner & Tuor, 2010a). Another possible motivator is social responsibility (cf. Wettstein et al., 2014).

cohorts, the decrease of one graduate resulted in a decrease of approximately half an apprenticeship training place (approximately -0.4) but no decrease in any school places (on the contrary, school places still recorded a slight increase of approximately +0.01; cf. Figure 5, right side). As a result, the proportion of school places increased disproportionately during periods of shrinking cohorts (Swiss Coordination Centre for Education Research, 2018: 120). Thus, apprenticeship training in companies or VET in general had to more or less completely absorb the consequences of the demographic decline, which was reflected, among other things, in an increasing oversupply of apprenticeship training places and thus in unfilled places (Schweizerische Koordinationsstelle für Bildungsforschung, 2018). An additional increase in the pool of potential applicants for apprenticeship training is possible, on the one hand, by adult education, e.g., through shortened apprenticeship training or direct admission to the Qualification Procedure (see Schmid et al., 2017; State Secretariat for Education, Research and Innovation, 2014b; Tsandev et al., 2017), and, on the other hand, in individual cases by the acceptance of graduates with a baccalaureate degree into apprenticeship training (cf. *maxon*).

Figure 3: Reaction of the number of apprenticeship places in firms and of school places in baccalaureate schools to changes in compulsory school graduates, 1988–2013



Source: Figure 112 from SKBF, 2018: 120; Calculations: Forschungsstelle für Bildungsökonomie der Universität Bern from data of the FSO.

Reading aid

The relative change in the number of apprenticeship places when the number of school graduates changes by 1 person amounts to a proportional reaction of between 0.4 and 0.5. As dual apprenticeship training absorbs on average approximately 60% of a year's cohort, a fully proportional response to changes in the number of pupils would require an increase of 0.6 in the number of apprenticeship places if the number of school graduates were to increase by one. In fact, however, the number of apprenticeship places is increasing by only half. The values were determined by means of multiple regressions involving all cantons (N = 416) and taking into account the influence of economic fluctuations.

Training participation of companies

Nevertheless, the participation of companies in apprenticeship training is currently still high in Switzerland. The training participation rate—i.e., the percentage of firms that provide dual apprenticeship training relative to all firms that are able to provide dual apprenticeship training—was 42 percent in 2009 (Strupler & Wolter, 2012: 158).[78] The willingness to train increases practically linearly with the size of the company: While over 30 percent of companies with fewer than ten employees train apprentices, almost 80 percent of companies with more than 99 employees and virtually all companies with more than 500 employees train apprentices (Strupler & Wolter, 2012: 159–160). In Switzerland—similar to Germany—large companies as well as small and medium-sized enterprises systematically participate in dual apprenticeship training. Through the broad participation of all types of firms in VET and through the cooperation of various

[78] When calculating this quota, companies that are not eligible for training are excluded because, for example, they are too small or too specialized (see, for example, Mühlemann et al., 2007b; Strupler & Wolter, 2012). Calculations of training participation based on complete surveys, e.g. the business census, include all companies, so that the quota is automatically lower. In the 1990s and 2000s in Switzerland, the proportion of training companies, i.e., the percentage of training companies relative to all companies, remained constant at approximately 18 percent (Müller & Schweri, 2012).

state and economic actors as VET partners in the development and updating of VET content, a continuous flow of innovative knowledge and highly qualified workers is ensured for all types of firms in the Swiss economy.[79]

Below we examine two aspects of the influence of VET on companies' innovative capacity. On the one hand, we consider the connection between qualification structures and firms' innovation outcomes, and on the other hand, we analyze to what extent this connection is moderated and fostered by corporate strategy, and by organizational and personnel policy measures.

3.2 Educational diversity and innovation outcomes of firms

As argued in Chapter 2.5 on the systemic level, an adequate skill mix can foster innovation if it combines different sources of knowledge, field expertise or practical experience and thus increases creativity.[80] Similarly, a good skill mix can also foster innovation at the company level (cf. Bolli et al., 2017). In *maxon* and *Bühler Group AG*, for example, R&D teams are deliberately composed of employees with different educational backgrounds—graduates of apprenticeships, PET programs and examinations, UASs, and FITs/UNIs—to increase the innovative performance of the company (see Box 4 and Box 6).

In general, the qualification structure of companies located in Switzerland shows a relatively high degree of educational diversity.[81] Only 2 percent of companies specialize in a single source of knowledge (cf. Bolli et al., 2017 and similarly Meuer et al., 2015). Various studies investigating the influence of educational diversity on innovation have shown consistently positive correlations for Switzerland.

A study by Bolli et al. (2017) focuses on the influence of vertical educational diversity, i.e., the composition of the workforce according to educational levels, on innovation.[82] They calculate a diversity index[83] for each firm in the KOF Innovation Survey (1996–2011) and estimate its influence on different innovation outcomes. The results show a positive relationship between educational diversity and innovation in the early stage of the innovation process (the discovery of new ideas and research paths) but not in the later stages (the commercialization of inventions). Further studies by Meuer et al. (2015) and Rupietta and Backes-Gellner (2019) examine whether educational diversity also has different effects on different types of innovation (radical, incremental or organizational innovation). Meuer et al. (2015) consider the diversity of qualification structures based on different levels and types of education. They find a positive link between educational diversity and radical, incremental and organizational innovation. However, they also show that these effects depend on the sector, the dynamics of the market environment and the HRM systems used by the firms (cf. Chapter 0), so the effects cannot be expected in general. Rupietta and Backes-Gellner (2019) further demonstrate the importance of heterogeneous qualification structures for firms in the traditional and high-tech manufacturing sectors. The results show that different vocational training qualifications are important both for small and medium-sized enterprises and for large companies and that they are particularly important for firms in a dynamic market environment. The authors also find that in more innovative firms, the knowledge flow between the various types of education is systematically supported and fostered by personnel policies and organizational measures (see also Chapter 0). In line with these findings, the *Novartis* case study (see Box 5) shows that educational diversity can be a crucial factor for innovation for firms in the pharmaceutical industry.

[79] The situation is different in countries without VET, such as the USA, where—at best—only a few large firms have to date systematically participated in dual vocational training (see Berger, 2013).

[80] From a theoretical point of view, the influence of educational diversity can—like any other diversity dimension—operate in two directions. The combination of diverse employees can actually lead to opposing effects (see Backes-Gellner & Veen, 2013; Bolli et al., 2017; Lazear, 1999). On the one hand, diversity advantages emerge. For example, firms have access to a broader knowledge base (compared to firms with a less diverse or a homogeneous workforce) through collaboration among individuals with diverse educational backgrounds. Bringing together different (technical, social and cultural) knowledge, field expertise, experiences, interests, values and preferences can lead to improved problem-solving capacity and decision-making. Due to these complementarities, the productivity of the team is higher than the sum of the productivities of the individual employees. On the other hand, diverse teams incur diversity costs. Differences in educational background and the resulting diversity of values and preferences can lead to misunderstandings, conflicts and distrust among employees. Access to the broader knowledge base therefore requires additional communication and coordination efforts. From a theoretical point of view, the effect of (educational) diversity therefore remains unclear.

[81] Based on data from the KOF Innovation Survey, Bolli et al. (2017) show that only 2 percent of the firms in the sample specialize in only one source of knowledge. The diversity index (0.50) calculated by the authors also points to a very heterogeneous qualification structure. Meuer et al. (2015) find a similarly high diversity value (0.51).

[82] Employees are classified according to their highest educational attainment: tertiary academic (UNI or FIT), tertiary vocational (PET and Advanced PET examinations, PET colleges, UASs), upper secondary (vocational and academic), or without a degree at upper secondary level (unskilled and apprentices). The authors assume that a higher degree of diversity leads to costs and benefits that have different impacts on different innovation activities. Considering innovation as a process, they argue that in the early innovation phase, when discovering new ideas and research paths, creativity—and thus diversity—is particularly important, i.e., the benefits outweigh the costs. In the later innovation phase, in which inventions are commercialized and aspects such as promotion of sales and distribution are therefore crucial, coordination and communication costs dominate, which is why diversity can have no (or even a negative) effect.

[83] Bolli et al. (2017) use the "Hirschman-Herfindahl Index" as the diversity index.

Box 5

Case study: *Novartis*

Novartis is a global pharmaceutical company with over 125,000 employees worldwide.[a] *Novartis* sells products in over 150 countries and generates annual sales of more than USD 49 billion. At their Basel location, *Novartis* has the global headquarters, the headquarters of the Innovative Medicines Division, the largest R&D center and part of the production. In addition, Basel is the training location for almost 300 apprentices.

Apprenticeship training ensures the supply of skilled workers by imparting solid theoretical basic knowledge and practical skills as well as fostering independent working methods and socialization into the firm culture. The advantages of the VET programs at *Novartis* are also internationally recognized: for example, graduates of the “Chemical Laboratory Technician EFZ” and “Biological Laboratory Technician EFZ” VET programs are regularly sent abroad, e.g., to the USA (and, in the past, to Spain or Singapore), as part of the promotion program. The feedback on the training quality of these graduates has been excellent; in particular, their autonomous working methods differentiate them from graduates from purely school-based educational institutions in these countries. For instance, while *Novartis* fills job positions with VET graduates in Basel, the company employs graduates with master's or even PhD degrees from universities in the same position in other countries.

Apprentices in (basic) research and development

For *Novartis*, the VET programs of “Chemical Laboratory Technician EFZ” and “Biological Laboratory Technician EFZ” are of particular importance, but apprentices are also trained in the occupations of commercial employee, information technology, automation, logistics, polymechanics, electronics engineer, office assistant and chemical and pharmaceutical technologists. [b] Approximately half of all apprentices are trained as “Laboratory Technicians EFZ” in biology or chemistry. Apprentices and graduates in the two primary occupations work in all fields of the business (oncology and hematology, immunology and dermatology, respiratory diseases, cardiovascular diseases, neurology, and ophthalmology). They are also employed in all stages of the innovation process: In (basic) research, they work primarily with UNI/FIT graduates with PhD or master's degrees; in development, they collaborate in particular with graduates from UASs. At *Novartis* Basel, apprentices and apprenticeship graduates thus often work at the innovation frontier.

VPET graduates in the innovation process—the Hit Generation Sciences Group as an example

The Hit Generation Sciences Group constitutes a concrete example illustrating the involvement of VPET graduates in the innovation process at *Novartis*. At the Basel site, the peptide sub-group consists of two chemistry and two biology laboratories with a total of seven “Laboratory Technicians EFZ” and four PhD graduates. The “Laboratory Technicians EFZ” took differing educational pathways. The majority initially graduates from a classical apprenticeship and then continued their education career (e.g., via PET college, university or VPET trainer education). In addition, the Hit Generation Sciences Group constantly participates in training at least one apprentice who basically performs the same work as all “Laboratory Technicians EFZ”.

The Hit Generation Sciences Group is concerned with new chemical starting points for classical medicines for all disease areas. The aim of the group is to search for chemical molecules that can be used where, for example, a certain protein is inhibited or activated due to a disease. The chemical molecule to be searched for should bind to this protein and carry out a desired action (e.g., activation or inhibition). The Hit Generation Sciences Group advises the research teams on the feasibility and chances of success of this molecule search; it also conducts experiments to find molecules (e.g., using the encoded DNA library) and provides a selection of hits (molecules) to the research group being advised. Thus, the Hit Generation Sciences Group and its VPET graduates play a central role in *Novartis'* innovation process.

The distribution of tasks within the Hit Generation Sciences Group has changed considerably in recent years. In the past, a PhD graduate was in charge of the laboratory management and assigned tasks to the “Laboratory Technician EFZ”. Today, the boundaries between laboratory managers and “Laboratory Technicians EFZ” are more fluid. Although “Laboratory Technicians EFZ” are still active mainly in direct laboratory work and are responsible for the technical implementation and production of the test compounds or assays, PhD graduates are more and more dividing into sole people/project managers and scientific leaders with little to none line function. The latter are also involved in bench activities. Conversely, “Laboratory Technicians EFZ” currently have more opportunities to also be involved in subprojects independent of their laboratory managers and to work with other project teams. The latest trend is the flexible distribution of tasks and skills along with project needs, meaning that the teams of technicians and scientific leaders can form, disrupt and reform at any given time, which is breaking with the classical laboratory manager / technician association. A high level of self-organization and autonomy is therefore mandatory. Project management, including advisory activities and budgeting in the early process stage, are still the exclusive responsibility of laboratory managers, i.e., PhD graduates. However, “Laboratory Technicians EFZ” currently occasionally also take over some line management functions when it comes to supervising new colleagues, students, guest scientists or apprentices.

In the Hit Generation Sciences Group, “Laboratory Technicians EFZ” (i.e., VET graduates) are involved in the innovation process in a variety of ways. Regularly, the “Laboratory Technicians EFZ” provide innovative inputs, e.g., in the context of chemical planning or the independent reaction search with IT tools in interaction databases. Laboratory managers formerly performed these tasks, but “Laboratory Technicians EFZ” are now also expected to be able to perform them, and they are becoming increasingly important. Discussions between laboratory managers, usually PhD graduates, and “Laboratory Technicians EFZ”, from whom in individual cases the best ideas may come, are also of great importance. “Laboratory Technicians EFZ” also introduced technological innovations into the laboratory work, e.g., advanced chromatography systems that were presented at a fair. In addition, they are particularly effective in innovations that facilitate daily work, e.g., cost-reducing or organizational innovations. As an example, in the Hit Generation Sciences group, “Laboratory Technicians EFZ” have developed, together with the IT group, an IT tool that enables online data entry and tracking of peptides to be synthesized. This tool facilitates both the work process (planning, synthesis and completion) and the organization of work, e.g., through a newly created and independent division of labor. VPET graduates are also significantly involved in innovations in research projects. For example, “Chemical Laboratory Technicians EFZ” from the Hit Generation Sciences Group are involved in research subprojects in which, for example, methods are evaluated to determine how (chemical) compounds can be better brought into the cell. The ideas for such subprojects often come from laboratory managers, i.e., graduates of UNIs or FITs with profound theoretical knowledge, but the concrete implementation and further development of the ideas take place in close cooperation with VPET graduates.

The combination of different sources of knowledge, e.g., from graduates from universities and VET, thus plays an important role in this and other stages and areas of innovation at *Novartis*.[c] The central advantage of VPET compared to purely academic education is its practical orientation and relation to the working environment, the company and its processes, while academic knowledge is more abstract and theoretically or analytically oriented. However, neither a purely practical nor a purely academic approach can address all problems; a variety of different knowledge types and skills, as well as a combination of different knowledge sources—i.e., a broad skill mix—is needed in the company’s innovation process.

Technological change and digitalization as a challenge: adaptations and updating of VET programs

Future challenges for apprenticeship training at *Novartis* arise due to technological change and, in particular, digitalization. Technological change not only leads to new approaches and methods in R&D processes but also entails new production processes. For example, the production of new types of blood cancer drugs is subject to new requirements that are addressed in “Biological Laboratory Technician EFZ” VET programs rather than in “Chemical and Pharmaceutical Process Technologist EFZ” programs. At the same time, the ratio of laboratory vs informatics based analysis work is changing dramatically due to modern informatics analytics capabilities. An experiment can be conducted in less than a week by a lab technician, but the informatics analysis and the respective decisions for new experiments take 2-3 weeks or more. This, in turn, slows down the pace for lab technicians. The focus is on providing high data quality so that the costs for data analysis are not unnecessarily high. This trend could make some jobs superfluous; however, it is more likely that this trend creates the need for more broadly skilled technicians (i.e., broader skills within their discipline, but also additional skills outside their discipline, such as basic informatics skills), but also the need for more efficiency due to increased time and quality pressure. To ensure that VET survives and can even support such new developments, adjustments in occupational competences are indispensable. The training association *aprentas* is mandated to initiate changes in the occupational content of the relevant VET programs. *Novartis*, one of 80 member companies of *aprentas*, is the main sponsor of this association and serves on its board of directors. Together with the other member companies, *Novartis* therefore plays a decisive role in shaping and promoting the above-mentioned and other necessary adjustments (additions and innovations but also reductions) in the VET content.[d]

Upgrading of skills and continuing education and training

In addition to the state-of-the-art VET programs, the continuous upgrading of skills and lifelong learning of employees play a central role for *Novartis* in its ability to innovate. In this context, *Novartis* generally trains a larger number of apprentices than it currently needs inhouse. On the one hand, this oversupply contributes to the general pool of skilled labor in the industry. On the other hand, it lays the foundation for upskilling activities and upskilling education programs (e.g. PET colleges or examinations, UASs), which *Novartis* deliberately fosters. The strong orientation towards upskilling and continuous education and training begins already during the apprenticeship. Apprentices can complete the vocational baccalaureate (Berufsmaturität) while doing their apprenticeship. Or their apprenticeship training can also be coordinated with a PET college program. In addition, apprentices have the opportunity to already attend courses at UASs during their apprenticeship training.[e]

Developments and challenges in the Swiss VPET system

The increased permeability of the Swiss education system in recent decades has opened a variety of educational careers that combine academic and vocational education. The many opportunities are recognized by apprentices and students and are regarded by *Novartis* as highly valuable, as graduates of diverse educational pathways bring heterogeneous knowledge and diverse perspectives to the workplace. For *Novartis*, the improved image of VET also plays an important role for the recruitment of apprentices, and the recently established UASs and the introduction of the vocational baccalaureate play an important role for the recruitment of highly skilled professionals.[f] Recently, however, according to experiences at *Novartis*, there seems to be a problem regarding UASs because of a tendency to reduce the amount of practical experience (years in the practice) of their graduates. In some cases, graduates of UASs spent almost their entire educational career within school but not in firms. This is the case, e.g., for graduates of Upper Secondary Specialized Schools (Wirtschaftsschule) who then attend a degree from a UAS in business administration. They therefore exhibit little practical experience and no longer have the skill mix of solid professional competences and application-oriented research skills that enabled the above-mentioned bridging function in R&D.

Internationalization can become another challenge for VET contributions to innovation if, due to a lack of knowledge of the VET system in international companies or among international managers, companies neglect VET and its value—and instead rely on education pathways that are known abroad but are not necessarily more successful for their tasks.

[a] Key information comes from interviews with Mr. Sandro Crameri, Head HR University Relations & Apprentices, on July 19, 2018, and with Mr. Samuel Hintermann, Senior Investigator, and Mr. Martin Pfeifer, Scientist, on October 15, 2018. Supplementary information was obtained from internal documents provided in confidence for our case studies.

[b] “Information Technologists EFZ”, “Commercial Employees EFZ”, “Office Assistants EBA” and “Electronics Engineers EFZ” support the finance, IT, HR and marketing departments at all levels of innovation and in all areas. “Logistics Technicians EFZ”, “Automation Engineers EFZ” and “Polymechanics EFZ” work mainly in production. “Chemical and Pharmaceutical Process Technologists EFZ” are employed primarily in production (in all areas and innovation stages) and today increasingly also in development; they constitute approximately one-fifth of the apprentices at *Novartis*.

[c] At *Novartis,* great emphasis is also placed on interaction between teams at different stages of innovation (e.g., R&D) to gain speed in the innovation process. For this reason, too, a good and balanced educational mix is consciously ensured in the composition of teams. For example, the area of competence of “Chemical Laboratory Technicians EFZ” has specifically been expanded (e.g., in chemical synthesis search), as this improves the interaction between “Laboratory Technicians EFZ” and PhD graduates (the latter thus become better acquainted with the state-of-the-art of the equipment and the technological possibilities in the laboratory).

[d] From the perspective of *Novartis*, the link between the professional experts, who drive forward the updating of Vocational Education and Training curricula, and the current developments in corporate practice and industry is good. One reason is that most professional experts, often teachers from vocational school, are themselves apprenticeship graduates and have already worked in the occupation. In addition, the teachers organize themselves in line councils and regularly exchange information with VPET trainers from firms on—among other issues—daily practice and technological innovation. Occasionally, however, there may be delays in the exchange of knowledge and thus in the updating of curricula if, for example, certain chemical processes cannot yet be communicated from VPET trainers of the firm to professional experts due to corporate strategy and confidentiality reasons. For example, “Chemical Laboratory Technicians EFZ” were for some time lagging behind the technological innovations: outdated approaches to technical calculations were still being taught at vocational schools, although these approaches were no longer necessary in new electronic laboratories. However, this gap was finally closed.

[e] The encouragement and support of upskilling and further education activities even goes beyond the apprenticeship period: via the *aprentas* training association—responsible for both VET content and, more recently, a PET college—the content of the laboratory technician VET program and their PET college programs are coordinated and combined. The aim is to bring VET graduates to the highest possible competence level during the training period.

[f] According to *Novartis*, the reforms in the VPET system as well as the more diverse career opportunities for VET graduates have significantly improved the standing and—promoted by SERI and the media—the reputation of VPET careers among young people and their parents,

3.3 Educational diversity and knowledge spillovers in different directions

As shown, the integration of various knowledge sources can have positive effects on the productivity and innovative capacity of firms. Knowledge spillovers between employees with different educational backgrounds therefore play a central role. In other words, the productivity of employees with one type of education can be increased through collaboration with employees with another type of education.[84]

Backes-Gellner et al. (2017) provide an empirical study of spillover effects between employees of different types of education. Whereas in general only spillovers from highly qualified employees to less qualified employees are examined[85], Backes-Gellner et al. (2017) investigate the question whether spillovers can also occur in the other direction, i.e., from apprenticeship graduates to university graduates—particularly in countries with a strong VET system. Their hypothesis is based on the fact that in countries with a strong VET system, different types of knowledge and different skills can be taught through different types of educational pathways (vocational vs. academic)—in contrast

[84] See Bonander et al. (2016), Feldman & Audretsch (1999), Feldman & Kogler (2011), Glaeser (2010), Liu (2015) for the importance of spillovers for regional growth and innovation.

[85] The assumption is that knowledge spillovers are unidirectional, i.e., from higher-qualified to lower-qualified employees (Martins & Jin, 2010; Moretti, 2004). In contrast, Backes-Gellner et al. (2017) argue that although such unidirectional spillovers may be plausible in countries with only one (or one dominant) type of education, the assumption of unidirectional spillovers is not necessarily correct in countries with education systems that provide several very distinct high-quality educational pathways like the VPET system in Switzerland or Germany.

to countries without a strong VET system, where skills are more similar in type and are just taught at different levels of education (secondary vs. tertiary). In the latter countries college graduates have basically just more of the same type of skill than non-college graduates. In contrast, in the former countries VET graduates are highly skilled despite not having a college degree. VET graduates have a different type of high level skills that college graduates do not possess despite their tertiary level education. However, both types of knowledge can be central to productivity and creative work and, in particular, to the ability to innovate. Thus, not only can VET graduates learn from university graduates, but university graduates can learn from VET graduates in countries with a strong VET system. Vocational and academic education therefore provide complementary skills, resulting also in "reverse spillovers" from VET graduates to university graduates. Backes-Gellner et al. (2017) test their hypothesis of reverse spillovers based on the Swiss Earnings Structure Survey (LSE). The results show that university graduates are indeed more productive if they work together with more VET graduates. The functional form of these "reverse spillovers", however, is inversely u-shaped; i.e., the effect is positive but becomes smaller as the number of VET graduates increases. [86] Educational diversity thus has positive productivity effects due to knowledge spillovers in different directions.

Similar conclusions can be drawn from the innovation effects after the establishment of UASs (cf. Lehnert et al., 2017; Pfister et al., 2018; Schultheiss et al., 2018) that have been shown in Chapter 2.5. The empirical findings show that with the establishment of UASs and the resulting increased skill mix, the patenting activities increase in the respective regions (cf. Chapter 2.5). Furthermore, analyses of job advertisements show that in addition to the newly available UAS graduates, an increasing number of VET graduates are employed for R&D-related tasks, which again points to positive spillover effects in various directions.

Box 6

Case study: *Bühler*

Bühler Group AG [a] employs more than 12,500 people worldwide[b] and generated sales of more than CHF 3 billion in 2018. The company's core technologies are mechanical and thermal process engineering. *Bühler* holds a leading global market position in procedures for grain processing and also for the production of pasta and chocolate, die casting, wet grinding, and surface coating.

Each year, the company invests approximately 4 to 5 percent of its sales in basic research and applied development. It generates half of its sales with products that are less than five years old. Over 90 percent of these investments are made in Uzwil, the main site of R&D. Innovation plays a central role for the company. For example, *Bühler* invested CHF 50 million in an innovation campus in Uzwil, which opened in May 2019.

At the Uzwil site, *Bühler* is currently training nearly 300 apprentices in the following occupations: "Apparatus Engineer EFZ", "Automation Engineer EFZ", "Casting Technologist EFZ", "Information Technologist EFZ", "Design Engineer EFZ", "Polymechanic EFZ", "Industrial Varnisher EFZ", "Commercial Employee EFZ", and "Logistics Technician EFZ".[c] VPET plays an important role in *Bühler* in many respects. It not only secures the company's (long-term) demand for skilled labor but also enables training that is tailored to the company's needs and that includes high-quality specialist knowledge as well as a high degree of networking skills, inter-cultural competences, and social skills. This combination of professional and interdisciplinary skills and competences is central to the innovative capacity of the company, e.g., to the speed of the innovation process.

Apprentices and innovation

Apprentices are involved in R&D processes right from the start. For example, apprentices in the VET programs "Automation Engineer EFZ", Information Technologist EFZ" and "Design Engineer EFZ" are directly assigned to the R&D area, where they participated also in basic research. In the research laboratories, they worked together with engineers for example to install measuring probes and contribute to the analysis of pasta drying processes. Apprentices in the fields of apparatus engineering and polymechanics also contribute to the company's innovative performance, particularly where more mechanical solutions are involved. This contribution was manifested, for example, in the annual Innovation Challenge[d], which takes place under the direction of the Chief Technology Officer. All *Bühler* employees worldwide (including apprentices) can form project teams and propose innovation projects. For example in 2018, an internal preselection of the proposed innovation projects led to 20 projects that were then evaluated at Federal Institute of Technology Zurich; at the end of the evaluation process, six projects were implemented. One of the six teams selected in the 2018 Innovation Challenge consisted exclusively of apprentices. On the team, apprentices from apparatus engineering, polymechanics and design engineering joined forces to work on a transnational innovation

[86] Different estimation methods, in particular fixed effect and IV estimations, confirm the robustness of the results.

project. The aim of the project was to drastically reduce dust emissions during the roasting process of coffee beans in countries without a stable electricity grid. The project group aimed to develop a mechanically (i.e., without electricity) operated machine that removes the skin from coffee beans with a mortar. By drastically reducing dust emissions, the machine should prevent damage to health, such as loss of sight. The apprentices were in charge of project management, developing prototypes and bringing the machine—as planned—to series production readiness within two years.

Heterogeneous skill mix and fostering of knowledge exchange

To ensure the company's innovative capacity, *Bühler Group AG* uses very heterogeneous skills in their employment structures. They deliberately include all types of educational pathways, i.e., graduates from VET programs, from PET institutions and programs ((advanced) PET examinations, PET colleges), from UASs, and from FITs and UNIs. This skill mix is deliberately chosen to benefit from the comparative advantages of the different educational types. Ideal for practical areas or for concrete implementations are apprenticeship graduates who, for example, have profound knowledge of assembly or automation and sometimes further specializations due to a PET qualification. VET graduates work together with graduates from PET colleges and from UASs. They speak the same language and have a shared perspective and knowledge with UAS graduates. UAS graduates are usually responsible for the management and coordination of the projects and can be employed for these tasks directly after completing their studies. Above all, they also act as an important bridge to graduates from the FITs and UNIs, who need at least one year of induction time due to their limited practical experience.[e] The latter are mainly active in basic research and strategic areas. They concentrate, for example, on analytical evaluations, theoretical basic calculations or questions about technological or social trends, e.g., how the population will be fed in the future and how this could be implemented technologically. For the implementation of innovations, collaboration with employees with good practical skills is always important. The R&D laboratories in Uzwil, for example, are approximately one-third to one-half staffed by employees with a FIT degree, e.g., from basic research in food technology. However, the laboratories also comprise a large number of specialists with vocational skills and knowledge, e.g., with an apprenticeship training in bakery or food technology and an additional UAS degree.

From *Bühler*'s perspective, two aspects are central to the company's innovative strength: first, an adequate skill mix of the above-mentioned diverse education and training graduates and second, an intensive knowledge flow between employees with different skills. Concerning the skill mix, all types of graduates are represented at *Bühler* across the entire spectrum of innovation activities—from basic research to practical implementation—albeit to a varying extent. For example, comparatively more FIT graduates are needed in basic research, while more VET and PET graduates are needed in application-oriented areas or practical implementation. Concerning the knowledge flow, it is essential for *Bühler* that there is always a good exchange of knowledge between all the different types of graduates. Therefore, *Bühler* systematically fosters the knowledge exchange by HR measures such as job rotation, teamwork and empowerment.

Fostering innovation at *Bühler* by teaching "soft skills" and interdisciplinary competences

Other crucial factors for *Bühler*'s innovation strength are interdisciplinary competences and soft skills such as leadership skills, networking skills, inter-cultural competences or project management. All these competences are systematically developed in-house from the beginning, i.e., during the apprenticeship. For example, apprentices are involved in the entire spectrum of company innovation activities from the start; this enables them to gain early and valuable competences at the innovation frontier and to participate in pushing the frontier. *Bühler* also fosters early development of other skills such as project management. Approximately one-quarter of apprentices take a four-month training course to become project managers during their apprenticeship training. During this time, apprentices work in mixed teams to generate solutions for real customers, they learn how to lead, document or present such a project and they learn how to work with customers from foreign cultures, such as China. Inter-cultural competences are also systematically developed through foreign assignments of apprentices. In the final year of their apprenticeship, apprentices can spend several months at *Bühler* locations in foreign countries. By doing so they can built international networks during their apprenticeship for example in China, Vietnam, South Africa, India, England, Brazil, France, or the United States; in addition, they also learn to understand other cultures and work mentalities.

To strengthen interdisciplinary competences, apprentices also rotate early in their training through various departments and specialist areas. As a result, they gain insight into related occupational fields, which systematically strengthens their interdisciplinary knowledge. For example, design apprentices go into automation to learn how to program or commission control cabinets, or into the metalwork department, where they learn how to implement simple designs using welding, gluing, riveting or soldering, or into mechanics to learn how parts are produced mechanically. *Bühler* considers these interdisciplinary competences, in particular networking skills across different departments or national borders, as key competences for its innovative strength. As technical and business problems become increasingly complex and can rarely be solved by a single individual, a broad mix of different skills and expertise, on the one hand, and skills that allow access to these various sources of knowledge—e.g., team orientation and inter-cultural competences—on the other hand, are seen to become ever more important.

Last but not least, *Bühler*'s new Innovation Center is architecturally designed for networking and contains approximately 300 mobile workstations so that employees—regardless of hierarchical level or department—can interact and collaborate with each other and various sources of knowledge can be accessed and exploited unbureaucratically and quickly. In this center, apprentices also learn how to reach colleagues who are helpful for their projects, even if they are already much further ahead in terms of experience, training or hierarchical level.

"Polymechanic EFZ" apprentice
Photo: *Bühler Group AG*

Selection of apprenticeship applicants and personnel development

At *Bühler*, apprenticeship training plays a central role in securing the supply of skilled labor in the long term. This is reflected, for example, in the company's goal of keeping two-thirds of apprenticeship graduates employed by *Bühler*. At present, this share exceeds 70 percent. Thus apprentices represents an important pool of (future) skilled workers and an important factor for the innovative performance of the company.

Therefore, the selection of apprentices is of particular importance to *Bühler*. The focus is less on academic performance than on the fit with the company and its tasks. Special consideration is given to passion and interest for the job, to special talents (e.g., imagination) and to social skills (ability to work in a team and social interaction as well as handling safety regulations, punctuality, etc.) but also to the learning curve during a Sniffing Program.[f] Through a good fit between apprentices and *Bühler*'s corporate culture and through adequate HR measures, *Bühler* aims at identifying and promoting the potential of the employees and to accompanying it by career management from the very beginning.

The development of apprenticeship graduates does not end with the final examinations. The vast majority of the workforce exhibits a variety of formal and informal continuous training. The development of apprenticeship graduates (and the rest of the workforce) takes place for example within the formal education system, e.g., at PET colleges, UASs or (via Passerelle) at the FITs. For graduates who take this path, it is important for *Bühler* that they are able to link their newly acquired—often theoretical—knowledge with the practical world of the company. They create this link, for example, by offering former apprenticeship graduates who are currently studying at a UAS or FIT to work at *Bühler* during their semester breaks.

When going into continuing further formal education and training, *Bühler* strongly encourages specialization, and not general formal programs. *Bühler* encourages training that is particularly valuable for its innovative capabilities and therefore offers for example selected VET specializations. It also encourages employees who come from a technical apprenticeship to go into continuous training to become field specialists, e.g. an "Automation Technician EFZ" trained in electrical or environmental engineering, in information technology or mechanical engineering. Continuous training for field specializations are given priority by *Bühler*, as other aspects—e.g. coaching or leadership—can easily be acquired in the form of postgraduate diplomas or courses.

"Automation Engineer EFZ" apprentice
Photo: *Bühler Group AG*

Employees with only general continuing training, however, are difficult or impossible to employ at *Bühler*. For example, *Bühler* does not encourage training programs that cover a multitude of areas, but not in sufficient depth. Encouraging employees to specialize is thus both an important goal and a challenge for the company. Another problem that *Bühler* identifies is that many apprenticeship graduates want to start a continuous education immediately after graduation. However, additional practical experience is essential to be able to link newly acquired knowledge with the real world and to transfer it into company practice. Likewise, *Bühler* sees a problem in the lack of practical experience of UAS graduates that come from a general baccalaureate schools (Gymnasium) instead of an apprenticeship training. They often come with only one year of labor market experience, which is simply not enough to acquire broad practical knowledge or to immerse oneself into a company's culture and processes.

Personnel development also takes place in the form of informal training. In addition to job rotation or international assignments, *Bühler* uses in-house training programs (e.g., to become a project manager), lifelong learning supported by an e-learning platform (including over 1,000 e-learning and blended learning courses). With this platform, employees can be individually developed and specifically upskilled.

Participation in the VET curricula updating process

Bühler is also involved in the development of new occupational curricula and actively participates in the process of updating of VET curricula (see also Chapter 2.2 and Box 2). Currently the integration of future-oriented teaching content such as learning a programming language in all technical professions is seen as one important update.

[a] Key information comes from an interview with Mr. Andreas Bischof, Head of Vocational Education and Training, which took place on December 5, 2018, at the premises of *Bühler Group AG* in Uzwil. Supplementary information comes from internal company documentation that was made available to us confidentially for our case studies.

[b] The 10 percent temporary employees are not counted.

[c] For English translations of the occupations, we use translations that are consistent with the remainder of the report to improve the readability of this report. Bühler internally uses „Mechanical Engineer" where we use "Polymechanic EFZ", "Industry Painter" where we use "Industry Varnisher EFZ", "Stock Clerk" where we use "Logistic Technician EFZ".

[d] The projects of the Innovation Challenge have multiple objectives. On the one hand, they should explore innovation potential and realize innovation projects, e.g., saving water, electricity or waste from foodstuffs by innovative optimization of processes. On the other hand, they are also intended to help build personnel networks within *Bühler Group AG* across national and divisional boundaries.

[e] An intermediate job level between UAS and FIT/UNI graduates is not necessary for a good cooperation of UAS and FIT/UNI graduates; however, postgraduate studies, e.g., in innovation management, can be advantageous for UAS graduates in this cooperation.

[f] A Sniffing Program is an internship for 8th or 9th graders with a length of a week or two, in which the apprentices get to know the work at a company and the company gets to know the student.

3.4 Moderators of the relationship between skill structures and innovation: Personnel policies, corporate strategy and organization

The previous chapters have shown that companies can combine different knowledge sources from graduates of different types and levels of education to increase their productivity and innovative performance. Theoretical considerations and empirical studies for Switzerland show that the strength of this effect depends on how the skill structures is aligned with the corporate strategies, corresponding personnel policy and the organizational frameworks. Rupietta and Backes-Gellner (2019) identify, based on data from the KOF Innovation Survey, different configurations typically associated with more innovative companies[87]. Their results show that the use of VET is crucial in almost all configurations of innovative companies in the traditional production sector, as well as in the high-tech production sector[88]; they also show that the innovation-fostering effect is enhanced by the use of tailored personnel policies and organizational measures.

The results of Rupietta and Backes-Gellner (2019) show several configurations of personnel policy and corporate framework conditions through which innovative companies are characterized. For small and medium-sized enterprises in the traditional manufacturing sector, a combination of VET and PET graduates complemented by teamwork to promote knowledge exchange within the workforce, are the typical components of more innovative firms. For small and medium-sized firms in the high-tech manufacturing sector[89], a combination of university graduates and PET graduates combined with empowerment measures and teamwork, is an important component of an innovation-promoting business structure.[90] For large companies in the traditional manufacturing sector and in a dynamic environment, PET graduates are also an important innovation factor; knowledge exchange in these companies is promoted mainly by job rotation but also by teamwork. Large companies in the traditional manufacturing sector and in a less dynamic environment, in contrast, mainly use a combination of VET and university graduates. For large high-tech companies, all sources of knowledge (VET, PET and university graduates) combined with teamwork to ensure knowledge exchange are components of particularly innovative configurations.

[87] They use the usual measurement values for incremental innovations as indicators of innovation.

[88] Meuer et al. (2015) also identify various innovation systems in Swiss companies and find that apprenticeship training is an important innovation factor. In the framework of a firm innovation system, which they describe with the keyword "organized learning", companies combine apprenticeship training with typical organizational learning practices such as job rotation and teamwork, with decentralized decision-making structures and with institutionalized cooperation with public research institutions. They find, however, that this type of operational innovation system is sector-specific. It is particularly important for companies in the modern services sector (e.g., financial services, etc.) and is particularly effective in generating radical innovations in that sector.

[89] PET graduates are also important for high-tech small and medium-sized firms operating in a less dynamic market environment. However, these firms do not have formalized HRM practices to foster knowledge exchange.

[90] An alternative innovation configuration in this manufacturing sector focuses primarily on university graduates sharing their knowledge through job rotation and teamwork.

The great importance of the relationship between the skill structures and personnel policies for companies' innovative performance is illustrated by the case studies presented here. For example, *Novartis* (see Box 5) deliberately conducts R&D in teams often consisting of PhD and apprenticeship graduates. At *maxon* (see case study in Box 4), employees with different educational backgrounds and from different areas are strategically combined in teams to foster the exchange of knowledge; moreover, competence-oriented collaboration with flat hierarchies is maintained across all areas and education levels.

Backes-Gellner et al. (2016) show that the home country of firms can also be an important factor in the design of innovative business configurations, but that home country effects can also be dominated by host country effects. The authors compare subsidiaries of US multinational companies in Switzerland and other European countries. They examine the question of the extent to which radical innovations at Swiss locations are always accompanied by simply adopting the HR practices of the US American parent companies or whether locations in Switzerland can also generate radical innovations by adapting their HR practices to Swiss institutions. With data from 69 subsidiaries and using the fsQCA method to identify configurations, the authors find that US subsidiaries in Switzerland do not generally follow the strategy of the US American parent company (i.e., they do not only focus on academic graduates and HRM practices of numerical flexibility). Instead, they use the particular advantages of country-specific conditions in Switzerland to create radical innovations. In Switzerland, for example, subsidiaries do not only work with a high percentage of academic university graduates; instead they are likely to work with apprenticeship graduates. At the same time, they use HRM practices of functional rather than numerical flexibility. In accordance with these results, Mühlemann (2014) finds that on average there is no significant difference between international and Swiss firms located in Switzerland in the willingness to train apprentices.

In summary, no single best innovation-enhancing skill structure exists across countries. Instead, it must be assumed that the skill structure alone is not decisive, but the combination of certain skill structures with appropriate personnel policies and corporate strategy measures is decisive for the expected innovation effects. It is evident that in Switzerland—with its well-developed and well-functioning VPET system—vocational qualifications in different forms and in different contexts and configurations play an important role even for international companies with parent companies in the US (or other countries that do not have well-developed VET systems).

4 Individual level

Individuals are central actors in the VET system insofar as it is individuals who ultimately decide in favor of (or against) a VET pathway and who later use (or do not use) their acquired skills in the workplace to increase productivity and innovation. In the case of young people, the pathway decisions begin with the decision to start their educational career with a vocational or an academic foundation. For adults in later life stages, the pathway decisions concern how to continue a formal educational career, and in the long term, decisions are about lifelong learning, participation in training and continuous adaptation to changing demands in the workplace. For the innovative capacity of an economic system, the willingness of individuals to reorient themselves and their ability and willingness to be occupationally mobile play important roles. For this purpose, the permeability of the education system and the resulting labor market outcomes are decisive.

In all these decisions, incentives, i.e., cost-benefit considerations in the broadest sense, are an important factor. Therefore, in the following section, we deal in more detail with the individual returns to different educational degrees and educational pathways. First, we examine occupational activity profiles and VET competence bundles.[91] We analyze how they contribute to mobility and flexibility in the labor market (at entry and throughout the work life). Second, the opportunities and incentives for individual further training and educational upgrading are considered. On the one hand, we analyze which formal training programs are basically available to VET graduates to obtain higher-level qualifications. On the other hand, we examine the extent to which these opportunities are used. We also examine how their use affects careers in both monetary form (e.g., through wage increases) and non-monetary form (e.g., through a better fit between qualifications and work).

4.1 Flexibility and occupational mobility with changing work requirements

In general, the flexibility and occupational mobility of workers depend on the transferability of the knowledge, skills and competences that they have acquired to date as well as the competences that they will acquire later in their education and career. The relevant question in connection with innovation is to what extent the skills and competences that individuals have acquired while being trained in their original occupations can be transferred to other career paths, new jobs, new companies or new occupations. The decisive question is to what extent the skills and competences can be transferred to new jobs that are created by innovation. With better transferability not only the individuals' willingness to innovate but also the companies' ability to innovate will increase. As theoretical and empirical studies show, transferability depends essentially on the specificity of the learned occupation.

A theoretical basis for the analysis of this question is provided by Becker's human capital theory (1962) and by the later extension of Lazear's skill weights approach (1999). Becker is the first to point out that a distinction must be made between general and specific human capital. The former is transferable across firms, while the latter can be used only in the training company (in the job in which the person was trained). The skill weights approach spells out both concepts. It assumes that “single skills” are distinguished from “skill bundles”. While each single skill (each individual competence, ability, knowledge or skill) is of a general nature and thus basically transferable, the skill bundle may be very specific and therefore rather difficult to transfer. Applied to VET, this means that VET occupations can be interpreted as skill bundles that bring together single skills with different weights. In this context, the skill bundles or the weights of the single skills of a particular occupation can be more or less specific—and thus more or less easily transferable. Whether a particular occupation (i.e., a particular bundle of skills) is more on the specific or on the general end of a spectrum of specificity depends on how unique its skills bundle is in comparison to the skills bundles of all other occupations on the labor market. This determines the degree of specificity of an occupation. The specificity degree determines how flexible and mobile graduates of VET programs are, how well they are prepared for changes in the world of work and whether they themselves can and are willing to contribute to change. A lower degree of specificity of training is a key determinant of the innovative capacity of the workforce and an important basis for the willingness of the workforce to participate in emerging innovations. In addition, a lower degree of specificity is accompanied by a broader skill mix, which promotes creative solutions and innovations. At the same time, a higher degree of

[91] How job profiles of occupations change (e.g., due to technological change) is investigated in the USA primarily through the task-based approach (see e.g., Autor (2013) or Autor et al. (2003)). The empirical findings for the USA (and also for some European countries) point, on the one hand, to a general decline in routine activities (Berger & Frey, 2016; Gregory et al., 2016) and, on the other hand, to a shift from manual and cognitive routine tasks to interactive and analytical non-routine tasks within occupations (Spitz-Oener, 2006). Rinawi and Backes-Gellner (2015) and the Expert Commission on Research and Innovation (2016) show that these predictions do not necessarily apply to countries with a strong VPET system.

A second approach considers not task bundles (e.g., routine tasks) but rather changes in competence requirements. Such studies examine the demand for competences associated with new technologies, e.g., in IT (see e.g., Düll et al., 2016), but also the (increasing) importance of generic competences such as leadership and management qualities or soft skills (see e.g., McGowan & Andrews, 2015).

specificity helps workers to go deeper to better understand operational processes or products, which is also important for innovation. In other words, there is a trade-off between the advantages and disadvantages of a lower or higher degree of occupational specificity. As a result, neither professions with a completely general skill bundle nor those with a completely specific skill bundle are usually optimal.

A number of empirical studies have dealt with the degree of specificity of occupations in Switzerland and its effect on the occupational mobility of VET graduates. The groundbreaking study by Mure (2007) is the first to use the skill weights approach to examine the specificity of VET occupations and the associated mobility of VET graduates. Subsequent studies in Germany by Geel et al. (2011) and by Eggenberger et al. (2019) and a more recent study in Switzerland by Eggenberger et al. (2018) also use the concept of the skill weights approach. In particular, they refine the measurement of single skills and skill bundles.

Based on German data, the studies by Mure (2007) and Geel et al. (2011) first show that VET occupations are highly heterogeneous in their degree of specificity. In addition, they show that individuals with more general VET occupations more frequently change their occupation than individuals with more specific VET occupations. If a change nevertheless takes place for an individual with a more specific VET occupation, the change is more likely to be accompanied by a drop in wages than a similar change for an individual with a more general VET occupation. However, the authors can also identify homogeneous clusters of occupations within which occupational mobility occurs comparatively frequently and across which mobility is rather rare. If career changes take place within such homogeneous occupational clusters, they often even have a positive wage effect (Geel et al., 2011; Mure, 2007).

The more recent study by Eggenberger et al. (2018), based on Swiss data, develops a more precise method for determining single skills and their weights. To this end, they use the learning objectives of all occupations set in the respective VET curricula. On this basis, they calculate a specificity degree for each occupation and analyze the mobility associated with different specificity degrees and the associated wages. The empirical results show that—as theoretically expected—individuals with more specific occupations change occupations less frequently in their later career and need more time to find a new job if they lose their job. At the same time, the findings show that there is a positive correlation between specificity degree and wages: Individuals with more specific occupations have higher wages than individuals in less specific occupations, all else being equal. Eggenberger et al. (2018) thus discover an important trade-off: curricula can be designed to either enhance occupational mobility opportunities (in case a change should become necessary) or to increase wage opportunities (for as long as workers are able to remain in their original occupation). These findings suggest that VET curricula should aim for a healthy balance of specificity degrees and that individuals must make their choice. When designing VET curricula, the advantages of specialization, on the one hand, and mobility potential, on the other hand, must be considered and weighed against each other (the latter being good preparation for changing environments, i.e., as a hedging strategy for unforeseeable changes).

Additionally, for Switzerland, Müller and Schweri (2015) examine the mobility of VET graduates. They investigate mobility between companies and between occupations (one year after completion of training). Their empirical findings show a high degree of mobility between companies in the first year, which does not entail any negative wage effects. At the same time, they show rather low mobility between occupations in the first year—which, if it does occur, is associated with negative wage effects on average.

In summary, the empirical findings[92] show that the skill bundles acquired in VET programs can be more or less specific, depending on the occupation. More general occupations have better chances for occupational mobility, while more specific occupations have above-average wages, i.e., a specificity premium, as long as workers stay in their original occupation.[93] By no means, however, are graduates of VET programs limited to their original occupation for the rest of their working life. On the contrary, they have a more or less wide spectrum of options: they can be mobile both between companies (within the same occupation) and between occupations (within or across companies). Occupational changes result in a reduction of wages only if the occupations are very specific or unique and if they do not fall within well-occupied occupational clusters. In such a case, it is more likely that a change to a more distant occupational skill bundle will have to be made. However, even if this happens, the losses are rather small and mainly cancel out the specificity premium.

The results also indicate that a systematic enhancement of a specific occupational skill bundle with widespread single skills (e.g., with knowledge of general-purpose technologies or digital skills (cf. Eggenberger & Backes-Gellner, 2019)) counteracts an overly high degree of specificity. Therefore, the ability to innovate

[92] Geel et al. (2011) and Mure (2007) for Germany, as well as Rinawi et al. (2014) for Switzerland, examine further questions on the specificity of VET occupations and obtain similar findings.

[93] Eggenberger et al. (2019) calculate the degree of specificity of academic and VET occupations. Their results show that the variance in specificity degree within academic and vocational occupations is much greater than between them. The variance in the specificity degree of academic occupations is also smaller than that of vocational occupations. They therefore conclude that it can no longer be assumed that academic education is more general than VET. This finding is reflected in the fact that the number of occupations in VET is just under 230, which covers the entire Swiss economy, while the number of degrees awarded at Swiss universities has a tenfold greater magnitude (between 1,700 and 2,200; see www.studyprogrammes.ch and https://berufsberatung.ch); in Germany, the number of university degrees even exceeds 19,000 (Hachmeister, 2017). Thus, these large numbers of university degrees indicate a higher degree of specificity than the much smaller number of VET occupations.

and the willingness to innovate can be systematically increased. Herein lies a considerable opportunity for the future development of the VET system as a means of generally improving Switzerland's innovative strength and preparing for a successful response to the emerging digitalization wave.

Generic competences and soft skills

Innovation-related change requires not only technical and subject-specific skills but also generic skills, such as the ability to communicate and work in teams and social intelligence[94]—or, generally speaking, the so-called “soft skills”.[95] A study by Salvisberg (2010) examines these soft skills using job advertisements from the Swiss Job Market Monitor and finds a steep increase in the demand for soft skills, especially in the 1990s. He attributes this increase to structural change, to the introduction of computer work and to organizational changes. The case studies presented above, from both the associations and the companies, show that soft skills will continue to gain in importance in the future (for further details, see the case studies on curriculum updating in Box 2 and Box 3). Such soft skills function within occupational skill bundles as generic competences that reduce the degree of specificity and increase the chances for occupational mobility (for examples on the relation between generic IT skills and occupational mobility cf. Eggenberger & Backes-Gellner 2019).

Such findings are taken into account in the standards for the design of new occupational profiles set by the federal government. In particular, the standards attach great importance to employability skills. These include, for example, the ability to work in a team or to participate in lifelong learning (cf. Zbinden, 2010). In this context, all learning locations—companies, vocational schools and inter-company training courses—play an important role. However, the recent literature increasingly assumes that training in a real company context has a particularly strong effect on the development of soft skills (cf. Bolli & Hof, 2018; Bolli & Renold, 2017; Hoeschler et al., 2018).[96] Even the recent international literature increasingly acknowledges that VET can have an advantage with regard to the development of soft skills or non-cognitive personality traits (cf. Heckman & Kautz, 2012).[97] Empirical studies exist for Switzerland.

For example, Bolli & Renold (2017) investigate the importance of different types of soft skills for apprentices and companies (“self-soft skills,” such as motivation, commitment, reliability and credibility; “social soft skills,” such as teamwork and communication skills; and “methodological soft skills,” such as efficiency, analytical thinking and creativity). Bolli and Renold also investigate whether soft skills can be better acquired in a company or a school environment. The results show that both companies and apprentices attach the greatest importance to “self-soft skills” and also to team and communication skills. The results also show that a company environment is generally more efficient in teaching these skills. Of the 22 soft skills, only analytical thinking and joy of learning can be better taught in a school environment, according to the results. All others are better learned in a company. However, the sample is limited to economics students at PET colleges, and the transferability of the results to VET learners at the upper secondary level may therefore be limited. A recent study by Bolli and Hof (2018) provides further insight by investigating so-called coping strategies, which correlate closely with the Big 5 personality traits. The authors compare behavior and coping strategies in response to stress for individuals in company-based apprenticeships and for individuals in school-based VET programs. The results show better coping strategies for graduates of company-based VET, which correlate with conscientiousness, emotional stability and agreeableness. Additionally, Hoeschler et al. (2018) investigate the development and effects of non-cognitive personality traits for company-based VET apprentices. They use established and standardized concepts of measurement to assess how non-cognitive personality traits change for a sample of 150 apprentices during their VET program. They find strong positive effects for conscience, emotional stability, and agreeableness and above all for grit (essentially the ability to push through difficulties; cf. Duckworth, 2016).

Basic vocational training therefore teaches not only occupation-specific vocational skills and competences but also soft skills. The latter are becoming increasingly important in the changing world of work. However, research on the exact role of VET in teaching these skills and their impact on labor market outcomes and innovation performance is still a comparatively new field of research. Further research on these issues is urgently needed in the future.

[94] Compare summaries by Aepli et al. (2017), Bolli & Renold (2017), Schweri & Iten (2018). Aepli et al. (2017) refer to studies by Düll et al. (2016) and McGowan and Andrews (2015), among others. According to the above-mentioned studies, generic competences such as overview knowledge, leadership and management qualities, creativity, interdisciplinary behavior and thinking, and the ability to analyze complex relationships and facts will gain importance in the future. However, the extent to which different competence requirements will change in the face of innovation-induced change remains unclear. Aepli et al. (2017) refer to German case studies and conclude that, for example, in digitalization, the importance of both domain-related and generic competences is increasing. However, statements of general trends are not yet possible.

[95] Bolli and Renold (2017) argue that hard skills and soft skills can be specified in different ways. While “hard skills” have a strong relation to experience and practice, soft skills include competences with a rather loose relation to experience and rather include interpersonal skills that are related to personality traits.

In addition to the term “soft skills”, the literature uses terms such as non-cognitive personality traits, character skills, non-cognitive skills or non-cognitive traits. They are characteristics of personality that are not recorded by intelligence tests but are measured by psychological constructs such as Big 5 (OCEAN), Grit, Self-Esteem, and Locus of Control. They have a strong effect on school performance and labor market outcomes of individuals and are malleable beyond early childhood (see e.g., Almlund et al., 2011; Borghans et al., 2008; West et al., 2016).

[96] In an empirical study with German data, Janssen and Backes-Gellner (2009) show that experience-based or social competences are less depreciated than competences relating to concrete technologies, products or processes.

[97] Heckman and Kautz (2014) suspect that workplace-based programs could be promising in teaching non-cognitive skills.

4.2 Upgrading of skills and continuing training and education in response to more demanding job requirements

Innovations are often accompanied by changes in job tasks and in required competences. These changes often—although not always—lead to higher qualification needs. The resulting impact on the labor market and on workers with different qualifications is controversial in the literature.

> According to the so-called polarization hypothesis, which dominates Anglo-Saxon research in particular, technological change particularly reduces the share of workers with middle skills (and increases the share of low- and high-skilled workers). For Switzerland or other countries with a well-developed VPET system, however, such developments cannot be confirmed, as Aepli et al. (2017), Rinawi and Backes-Gellner (2015), Schweri and Iten (2018) and the Expert Commission on Research and Innovation (2016)[98] show. In Switzerland, the occupations of middle-skilled workers have a much broader range of skills and activities than those of middle-skilled workers in the USA. As a result, it is relatively easier in the USA than in Switzerland to fully replace the tasks of middle-skilled workers with technology.[99] Murphy and Oesch (2017) also find no signs of job losses for middle-skilled workers.[100] Instead, they find a tendency to upgrade such jobs.[101]

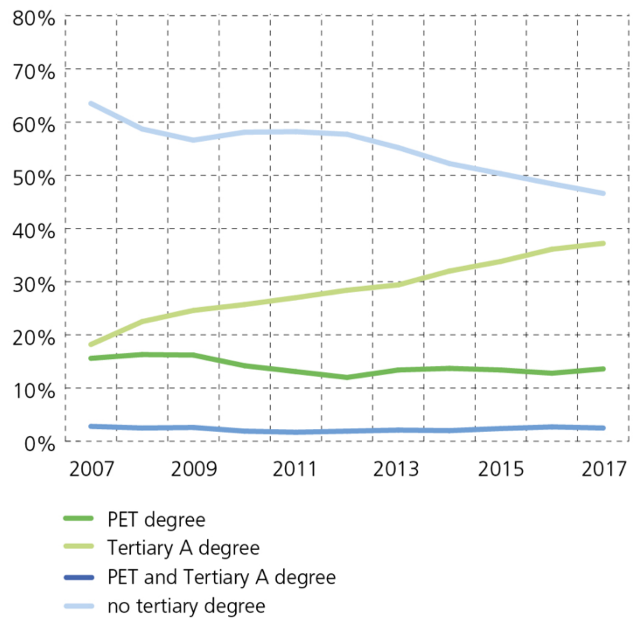
For such an upgrade, Switzerland's VPET system again provides good conditions (cf. Falk & Biagi, 2015; Wolter et al., 2015). First, VET in Switzerland provides future-oriented occupational skill bundles due to a systematic curriculum updating process, as described in the previous chapter. Second, as described above, VET facilitates a high degree of mobility between companies and across occupations for its graduates.[102] Third, VET also focuses on generic skills, such as soft skills or methodological competences, which are becoming increasingly important (cf. Chapters 2 and 4.1).

In addition, the VPET system offers VET graduates manifold opportunities for educational upgrading due to its strong connections to all parts of the education system, including PET colleges, PET diploma examinations, Advanced PET diploma examinations, UASs, UNIs and FITs. Such a portfolio of formal education opportunities creates excellent conditions for workers to upgrade their skills when jobs are upgraded (because they can then systematically expand their original occupational skill bundle).

At the same time, the diverse portfolio of educational opportunities provides an incentive for young people to start their educational career with a VET degree (Wolter & Ryan, 2011) because it provides them with attractive educational upgrade options and career paths even after graduation.

Descriptive statistics from the Swiss Federal Statistical Office show that the wide range of upgrading options is frequently used and is usually profitable. The share of 30- to 34-year-olds with tertiary degrees has risen continuously over the past ten years from 35 percent to over 50 percent (Figure 6). At the same time, the number of PET degrees has not decreased, it remained constant at approximately 15 percent, while the number of UAS graduates has risen (Figure 6).

Figure 6: Share of upper-secondary- and tertiary-level qualifications (percent) in relation to the population aged 30–34



Source: Calculations based on FSO data, Swiss Labor Force Survey (SAKE 2007–2017).

Figure 7 shows that since 2012, the proportion of UAS and universities of teacher education graduates—measured against the proportion of the working population—has been even greater than the proportion of UNI/FIT graduates, but this is partly due to structural breaks in available degrees (new occupations in the

[98] Expert Commission on Research and Innovation (2016: 57, Box B 2–6).

[99] Aepli et al (2017) refer to Marsden's (1999) "theory of employment systems", which attests high adaptability to technological change of the German (and Swiss) labor market because skilled workers in these countries show a high degree of autonomy in the workplace and of mobility between companies due to their VPET systems.

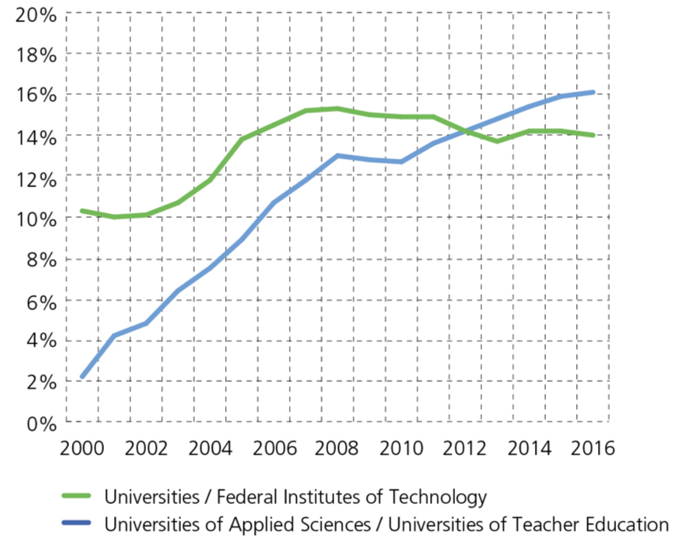
[100] Oesch and Rodriguez Menes (2011), however, find certain signs of polarization in Switzerland for the period between 1996 and 2008.

[101] In contrast, compare Oesch & Rodriguez Menes (2011).

[102] For coping with structural change, mobility is a central factor (Rütter et al., 2017).

fields of health, social work and the arts as well as new Bologna-compatible degrees) and immigration.

Figure 7: Share of graduates from "Universities of Applied Sciences / Universities of Teacher Education" and "Universities / Federal Institutes of Technology" (in percent) in relation to the working population of Switzerland



Source: FSO—Students and University degrees

In addition, many empirical studies show that vocational or mixed educational paths also generate competitive returns to education (cf. Chapter 4.3). For example, empirical studies by Backes-Gellner and Tuor (2010b) and Pfister et al. (2017) show that permeability is frequently used and that mixed educational paths have a comparatively high individual educational return (with comparatively low risk) (see also Chapter 4.3).

The opportunities for upgrading skills are thus well used and create a good foundation for the continuous development of the workforce in connection with process or product innovations.[103]

The empirical results of so-called mismatch studies, which show a low mismatch for VET graduates in Switzerland, allow similar conclusions to be drawn. Mismatch means that there is no (or hardly any) match between the skills, knowledge and competences learned by the workers and those required by the employers to perform the workers' specific jobs (cf. Buchs & Buchmann, 2017; Eymann & Schweri, 2015). The empirical findings for Switzerland indicate that the match in the Swiss labor market is generally good and, in international comparison, even excellent (see Figure 2 in Chapter 2). Furthermore, there is no evidence for an increase in mismatches in the last 15 years (cf. Aepli et al., 2017). Eymann and Schweri (2015) also show that individuals with a VET degree are not disproportionately affected by mismatch and conclude that the mobility of VET graduates is greater than previously assumed. Recent results from Buchs and Buchmann (2017) even show that the mismatch rates are lowest for VET and PET graduates.

Furthermore, Pfister et al. (2018) and Lehnert et al. (2017) show that through educational upgrading in MINT subjects at UASs, the corresponding graduates are not only well absorbed by the labor market but also make a substantial contribution to the innovative power of the Swiss economy (measured in terms of the quantity and quality of patents) (cf. also Chapter 2.5). The case studies on *maxon* and *Bühler Group AG* (Box 4 and Box 6) show that UAS graduates from MINT fields are clearly distinguishable from graduates with PET degrees and with FIT/UNI degrees but that this diversity is essential for the innovation process in Switzerland.

To what extent this applies to other areas and what advantages or disadvantages it entails remain the subject of further research. For example, health workers can be trained at UASs or at PET colleges. The former training takes place almost exclusively in French-speaking Switzerland, while the latter is more widespread in German-speaking Switzerland. Questions remain regarding whether the profiles of these alternative tertiary education programs are sufficiently clear (Schweizerische Koordinationsstelle für Bildungsforschung, 2018: 238) and to what extent they can be equivalently utilized.

In summary, however, Switzerland's VPET system, with its manifold possibilities for development and employment, prepares the workforce well for ever-changing working environments. It enables a high degree of mobility (between companies and occupations) for VET graduates, and it has a well-developed system of continuous training opportunities (including tertiary vocational and academic degrees) adapted to a wide range of needs. Through the breadth of VET programs, it also prepares students for a wide range of *non-formal and informal*[104] continuous education and training opportunities, which is also crucial for the innovative capacity of the economic system.

From the perspective of innovation, the diversity of VPET is a particular strength of the Swiss overall education system, as it is an important prerequisite for coping with changing and naturally unpredictable job requirements. A broad range of different

[103] Companies regard competence acquisition through mobility within the company (by moving to different departments and areas) or mobility between companies rather than attending a tertiary educational institution also as very valuable (see Box 2, Box 4 and Box 5).

[104] The Continuing Education Act (Weiterbildungsgesetz, WeBiG, Art. 3) distinguishes three different types of education. 1. Formal education includes standardized programs at the upper secondary level (VET programs, VET colleges, baccalaureate schools), PET degrees (PET examinations, Advanced PET examinations, PET college programs) and university degrees (bachelor's, master's, doctorate). Formal education is regulated by law and leads to federally recognized degrees. 2. Non-formal education is regulated by the WeBiG and includes structured continuing education outside formal education, e.g., workshops, self-organized courses, and continuing education at universities (CAS, DAS, MAS). 3. Informal education takes place outside structured and regulated courses and includes individual learning or learning on the job.

educational upgrading options is a good prerequisite for individuals to cope with innovation-related change and at the same time creates the necessary motivation to contribute to the systematic advancement of innovation.

4.3 Employment trajectories, career opportunities and incentives for further training and innovation

In addition to promising career prospects, the attractiveness of employment trajectories and opportunities for educational upgrading within the VPET and the overall education system are essential for talented individuals to start a VET program. Important incentive factors are competitive wages and career options. The calculation of rates of return to education[105] is one way to quantify the attractiveness of career paths and opportunities for advancement.

Although international studies often find lower rates of return for VET careers than for academic careers (cf. Conlon, 2006 for the UK; Heijke & Koeslag, 1999 for the Netherlands; Ryan, 2001 for the USA), empirical findings for Switzerland show fairly uniform positive rates of return despite the fact that different studies use different data and methods[106] to calculate the rates of return (see, e.g., Backes-Gellner & Geel, 2013; Balestra & Backes-Gellner, 2017; Cattaneo, 2011; Sheldon, 1992; Weber, 2003; Weber & Wolter, 1999; Wolter & Weber, 1999).

Both at the upper secondary level and at the tertiary level, the returns to VET programs are roughly the same as and, in some cases, even higher than those of academic programs. In addition, Balestra and Backes-Gellner (2017) show that the returns within all pathways are very heterogeneous and that the average returns do not apply equally to all individuals. They find, for example, that although an academic pathway yields higher returns at the upper end of the income distribution than a vocational pathway, there are no differences in return rates across the two pathways in the middle income range. In the lower income range, the vocational pathway yields even higher returns than the academic pathway. This means that for the majority of the labor force, VET pathways bring the same or even higher rates of return than academic pathways. In an early study, Wolter and Weber (1999) calculate private returns to education based on a cost-benefit model and find significant positive effects for all non-compulsory formal education programs. They do not find significant differences between vocational and academic pathways at the upper secondary and tertiary levels. Weber (2003) calculates not only private but also social and fiscal returns to education[107] for vocational and academic programs; the results show equally high, and in some cases even higher, private, social and fiscal returns to vocational pathways.[108] Cattaneo (2011) calculates the returns to PET colleges, PET diploma examinations, and Advanced PET diploma examinations. She finds strong and significantly higher incomes for individuals with these qualifications than for individuals without such education at the tertiary level.[109] Her cost-benefit calculations also show that the net benefits remain positive regardless of whether the graduates of these programs bear only part or all of their costs. Cattaneo concludes that educational upgrading within the PET system is always a good investment for the individual. Pfister et al. (2017) additionally show that differences and variance in income depend more on the chosen subject area than on the type of education (vocational or academic). MINT or business degrees have higher returns regardless of the type of education, while, for example, humanities degrees on average have lower returns regardless of the type of education.

Moreover, analyses of the risk of unemployment or the variance in wages also lead to positive results for VPET. Backes-Gellner and Geel (2013), for example, investigate the wages, unemployment risk and wage variance of graduates from academic universities vs. UASs immediately after graduation (at labor market entrance) and at a later stage (five years after graduation). Their results show higher average wages for UAS graduates and a lower wage variance at the beginning of the career; the unemployment risk is approximately the same for both types of education. In the

[105] Private returns to education generally refer to wage differentials due to differences in the number of years of formal education (State Secretariat for Education, Research and Innovation, 2014a).

[106] A widely used method is the Mincer wage equation (Mincer, 1974). Here the logarithmic wage is regressed on the number of years of labor market experience (to determine the age-income profile) and the number of years in training. Therefore, the returns to education are calculated in the sense of a return to an additional year of training. In addition, cost-benefit estimates calculate the (private) returns to different educational pathways by taking into account the costs. These include direct costs (e.g., tuition fees), opportunity costs (income lost during education) and (future) unemployment risk (see e.g., Backes-Gellner & Tuor, 2010b; Weber & Wolter, 1999).

[107] Private returns to education take into account relative wages in the labor market and individual education costs; social returns to education take into account total expenditure on education and any positive externalities. When calculating fiscal returns to education, tax progression is also taken into account.

[108] In contrast, Hanushek et al. (2017) argue that VET provides much more specific human capital than academic education. Thus, they are that although VET may enable easier entry into the labor market, it might also entail a greater risk of depreciation and obsolescence in the case of technological change. The authors thus suggest that there is a trade-off between initial integration into the labor market and longer-term career opportunities. For Switzerland, however, these assumptions cannot be substantiated, neither theoretically nor empirically. From a theoretical perspective, VET is not necessarily specific, just as academic education is not necessarily more general (cf. Chapter 4.2, in particular the relative number of different VET or tertiary degrees, as well as footnote 108). From an empirical perspective, the authors themselves provide counterevidence but without emphasizing it in their conclusions. For Switzerland, the lifetime income (income over the entire working life) of individuals with a VET background is not lower than that of individuals with an academic background (in contrast to other countries). In Switzerland, the lifetime income of individuals with VET degrees is higher than that of individuals with academic degrees.

[109] The difference is between 3 and 16 percent for PET and Advanced PET examinations and between 7 and 25 percent for PET colleges. The high range of income gains is due to different estimation methods: With fixed effects estimates, unobservable time-invariant characteristics, e.g., intelligence, are controlled; the estimated results (3 and 7 percent) thus represent the lower limit of the effect. Conversely, Cattaneo interprets the results of the OLS estimate (16 and 25 percent) as the upper limit. It can therefore be assumed that the income gain for PET examinations is somewhere between 3 and 7 percent and for Advanced PET degrees between 16 and 25 percent.

later career stage, the wage differences between UAS and university graduates disappear; however, UAS graduates still have a lower unemployment risk. In addition, mismatch studies by Eymann and Schweri (2015) and Buchs and Buchmann (2017) provide evidence that graduates of different VPET programs are adequately employed given their qualifications, as they find only a small mismatch.[110]

Furthermore, the returns to education of mixed educational pathways are also competitive. Mixed educational pathways include individuals who started their educational pathway at the upper secondary level with a VET degree and completed their educational pathway at the tertiary level with an academic degree. Mixed pathways also include individuals who started their educational pathway at the upper secondary level in the school system and then switched to a vocational program (PET or UAS). Individuals with mixed educational pathways have the same or even higher average incomes and, at the same time, often lower income risk.

Backes-Gellner and Tuor (2010b) analyze the private educational returns of individuals with tertiary education degrees and such mixed educational pathways. In addition to rates of return to education, they calculate income risks (i.e., the variance in income) of different educational pathways. Their empirical results show the highest average returns for mixed pathways, with approximately the same low-income risk for all educational pathways. Pfister et al. (2017) report corresponding results: Differences in income are determined more by the educational field (e.g., Health vs. Management) than by the type of education (vocational vs. academic). They also show that combinations not only of different types of education (vocational and academic) but also of different educational fields (e.g., management and MINT) are rewarded with income gains.[111]

With regard to mixed educational pathways, Backes-Gellner et al. (2010) also show that individuals with mixed educational pathways are more likely to become entrepreneurs than individuals with purely vocational or purely academic pathways. At the same time, the results show that—as would theoretically be expected—entrepreneurs on all educational pathways on average take higher risks than employees. [112] The higher probability of becoming an entrepreneur with a mixed educational path (compared to a purely vocational or purely academic path) can be well explained by Lazear's jack-of-all-trades theory. Entrepreneurs need broader and more balanced skill bundles, which are more likely to result from mixed educational paths (cf. Backes-Gellner et al., 2010).[113]

The empirical findings on various educational pathways in Switzerland and the associated labor market outcomes thus show that a VPET pathway is a competitive and attractive alternative to an academic pathway. With a vocational or mixed educational pathway, individuals can expect attractive employment paths, career options and promotion prospects. This is an important prerequisite for talented individuals to select themselves—according to their preferences and abilities—into the different VPET pathways. This ensures a well-rounded skill mix of highly qualified vocationally and academically trained workers at the systemic and company levels.

[110] In line with this are the results of a study by Lehnert et al. (2017), which shows that after the establishment of UASs, companies in the affected regions actually employ UAS graduates for R&D positions.

[111] The authors additionally show that differences in income are determined more by the educational field (e.g., health vs. management) than by the type of education (vocational vs. academic).

[112] The authors furthermore show that differences in income are determined more by the educational field (e.g., Health vs. Management) than by the type of education (vocational vs. academic).

[113] At the same time, entrepreneurs are more willing to take risks and therefore also have higher income variations (cf. Backes-Gellner et al., 2010).

5 Conclusions and challenges

In summary, the study shows that the VPET system in Switzerland is an essential part of the innovation system. Through various actors and mechanisms, it makes an important contribution to the innovative capacity of the Swiss economy.

The VET system creates a workforce with profound practical knowledge and a wide range of professional skills, including methodological and social skills. Workers with VPET qualifications are trained according to curricula with content that is regularly updated and geared towards the innovation front. This is vividly illustrated by the case studies on curriculum updating for the MEM occupations and the dental technician occupation that are presented in Box 2 and Box 3. The breadth of their training makes VET graduates flexible and mobile, increasing their ability and willingness to participate in and drive innovation in companies.

Accordingly, empirical studies find positive innovation effects for companies participating in VET. Companies that train apprentices are more innovative than companies that do not. Companies with a broad skill mix composed of graduates from VET, from PET, from UASs and from academic universities are more innovative than companies with a less broad skill set. The case studies on *Novartis*, *maxon*, and *Bühler Group AG* illustrate these relationships and underscore the importance of VPET in general and of a broad skill mix and synergy between different sources of knowledge for innovation in companies in particular (see Box 4, Box 5, and Box 6). Graduates of UASs function as important bridges between VET graduates and UNI/FIT graduates. The innovation effects of a diverse skill mix can be demonstrated for different types of innovations as well as in different industries, market environments and company sizes.

From an innovation perspective, the diversity of career opportunities and the high level of occupational mobility represent additional strengths of the Swiss VPET system, as they are important prerequisites for coping with changing and naturally unpredictable job requirements. Innovation-related change requires not only particular occupational competences but also more general soft skills, such as teamwork, self-organization, and communication skills. Empirical studies show that the company as a learning location, which is at the center of all dual VET, is particularly effective in developing such soft skills.

Vocational Education and Training thus supports and promotes the innovative capacity of Swiss companies and the economy as a whole in a variety of ways. However, at different levels, there are important prerequisites or structural building blocks that are decisive for these innovation effects.

At the *systems level*, a first important building block for the innovation contributions of the VPET system is the so-called VET-partnership, in which the state and Organizations of the World of Work, including companies, work together at various points of the VPET system. This ensures the high quality and future orientation of Vocational Education and Training in Switzerland. A first building block for the innovation effects is the systematic curriculum-updating mechanism through which all VET curricula are regularly updated (cf. case studies on the revision of MEM occupations in Box 2 and the dental technician occupation in Box 3). A second building block is the permeability of the education system since high permeability creates good conditions for workers to adapt to and to drive changing workplaces.

At the *company level*, there are two essential building blocks for the contribution of Vocational Education and Training to innovation: first, a sufficiently broad participation of different types of companies in VET (large vs. small, innovative vs. traditional, production vs. services sector, etc.) and second, a broad company skill mix. The innovation effects in companies are intensified when companies use complementary configurations of personnel and organizational measures as well as a compatible corporate strategy. There is no single best approach to innovative company configurations, but in Switzerland, in many innovative configurations, the presence of a workforce with VPET degrees is an important element.

At the *individual level*, there are two building blocks that are essential for the innovative capacity of the VET system. First, incentives in the education system and in the labor market must be designed in such a way that talented young people voluntarily choose a VET path. Second, individuals with a VET degree must be equipped to meet changing job demands in the short run and to upgrade their jobs through a variety of opportunities for formal educational upgrading and lifelong learning in the long run.

As the empirical studies for Switzerland presented in this study show, the above-mentioned conditions are currently well met in Switzerland. However, addressing major challenges in the future is crucial for maintaining the high innovative capacity of the Swiss system in the long term. Major challenges arise at all three levels.

At the systems level, there are two challenges.

1. Balancing of heterogeneous interests in the VPET system and a continued broad participation of companies in VET.

An important challenge is to ensure a balance of heterogeneous interests between different types of companies in the VPET system and to continuously ensure a broad participation of different companies in VET. There is, for example, an area of tension between companies that are closer to or farther from the innovation frontier, namely, with regard to future jobs and curriculum content. While from an innovation perspective it is favorable to give priority to innovative content from the innovation frontier, the continued broad participation of all types of companies in apprenticeship training also presupposes a balancing of interests. This balance can be ensured, for example, by the appropriate differentiation of occupational profiles, by inter-company training centers or by joint training and sometimes inter-company training courses. Therefore, Organizations of the World of Work are of crucial importance. They must continue to support a forward-looking balance of interests while at the same time ensuring that the educational content is as close as possible to the innovation frontier in terms of Switzerland's innovative capacity.

2. Systemic coordination between VPET institutions and academic education institutions

A second challenge at the systems level is adequate systemic management and coordination between institutional developments in VPET and academic education. This challenge is apparent at the upper secondary level, for example, in the problem of too few VET applicants that is driven by an overproportional increase in schooling places at baccalaureate schools (Gymnasium). It can also be seen at the tertiary level, where there is a danger that UASs dilute their independent profile and position themselves in competition with universities or PET programs. For example, some UASs are moving away from their original professional and application orientation towards a more theoretical university type of profile.[114] Some UASs and some of their fields are increasingly targeting graduates from the general education system (Gymnasium). Such developments not only distort career paths for VET graduates but also weaken the bridging function that UAS graduates fulfill at the workplace in the current innovation system.[115]

An increasing blurring of the originally clear profile of UASs is also manifested by some UASs competing with PET colleges, e.g., by introducing Master of Advanced Studies (MAS) programs[116] at UASs. Also in the context of transforming VET programs into academic education programs (e.g., programs in health and social services at UASs)[117], the question arises as to the effective need for such academic degrees in relation to more practice-oriented and professionally trained VET and PET graduates.[118] An important task for the future is therefore the systematic observation of such individual developments and, above all, a systematic coordination between the VPET and the higher education system. For all these developments, it is important that they do not take place in an uncoordinated manner but that there are coordination bodies between higher education and VPET authorities that investigate such cross-system issues and clarify any regulatory requirements with the relevant federal and cantonal authorities.

At the company level, there are three main challenges.

1. Participation of (innovative) companies in the VPET system

To ensure that VET curricula are continuously updated, the participation of innovative companies, especially in the curriculum development and updating process, is key. Since there are no empirical studies on this topic, it is not possible to estimate whether the participation of companies has changed (and, if so, how this change is distributed among different sectors or occupations). However, this aspect should be carefully monitored in the future, as it plays a crucial role in the innovative capacity of the VPET system. This means that in this regard, there is first and foremost a need for research.

2. Participation of new and of international companies in the VPET system

Another challenge for Vocational Education and Training is the increasing number of new companies and new company organizational forms or of international companies that have no VET traditions and may therefore be reluctant to participate. Regarding international companies, the significance of the problem cannot be determined unambiguously. While simple descriptive comparisons may well suggest that the training participation of international companies is lower than that of domestic companies,[119] Mühlemann (2014) show that this is not the case when regional and sector-specific differences are taken into account. [120] Observable cases of international tech

[114] In this context, the term “academization (Akademisierung)” is often used in reference to universities of applied sciences in the German language, but the use of the term “academic” in this discussion is generally problematic (cf. Renold, 2015).

[115] For examples of bridging function and upcoming problems see case studies in Boxes 4 to 6).

[116] In many cases, MAS participants are not even aware that they are obtaining not a formal academic degree but a (non-formal) continuing education certificate (from a UAS). There is a major qualitative difference between such a (non-formal) continuing education certificate and a formal, federally recognized PET degree (higher education institutions like UASs set their own qualification standards for the continuing education certificates and are not subject to external control, in contrast to federally recognized VET or PET examinations). Such continuing education certificates also distort ISCED-relevant statistics.

[117] An uncoordinated expansion of programs at higher education institutions (e.g., the training of nursing specialists only at UASs) would also have consequences for admission. Without lowering the requirements for the entrance qualifications (Fach-, Berufs- or gymnasiale Matura), a further increase in UAS programs in the nursing professions will not be possible. This in turn would have negative consequences for the whole education system.

[118] Furthermore, a question arises regarding to what extent publicly funded higher education providers (UASs) with their strongly growing continuing education certificates contribute to a gradual crowding out of privately funded education providers (e.g., OdAs). If OdAs are no longer able to carry out federal examinations, the position of the VPET system will be weakened in Switzerland because OdAs are dependent on the income from examination fees to cover the costs of their VPET organization and contributions to the whole VPET system. In other words, if the OdAs, which develop, update and govern the educational curricula in VPET, are weakened, this weakening will become a disadvantage for the entire Swiss education system, especially in the age of digital transformation and rapid change.

[119] Cf. Mühlemann & Wolter (2007), Mühlemann et al. (2007a), Mühlemann et al. (2007b), Schweri & Müller (2008), Wolter et al. (2006).

[120] According to Mühlemann (2014), international companies with fewer than 50

companies [121] that participate voluntarily in apprenticeship training in their Swiss subsidiaries indicate that the problem generally is solvable. However, it should be monitored and empirically studied.

3. Coping with a decreasing number of compulsory school graduates and VET applicants

A further challenge for companies is the decreasing number of VET applicants, which leads to increased difficulties in recruiting a sufficient number of suitable apprentices and to an increasing number of unfilled VET training places. The decreasing number of applicants is due not only to demographic developments, i.e., a reduced number of young people due to low-birth cohorts, but also to a lack of adaptation of the number of places at baccalaureate schools (Gymnasium) in the course of ever-shrinking cohorts. Instead of a proportional reduction, baccalaureate schools have even expanded their school places on average despite shrinking cohorts. This means that the VPET system must fully bear the burden of shrinking student numbers, which has counterproductive consequences for Switzerland's education and innovation systems.

Individual Level: Ensuring attractiveness of VET path among young adults and parents

At the individual level, there is one key challenge to the innovative capability of the VPET system, namely, ensuring the attractiveness of a VET path to highly talented young individuals, especially in times of shrinking birth cohorts. As shown above, VPET offers attractive career opportunities in terms of unemployment risk, income, promotion and occupational development paths. In the case of social status, however, academic education is sometimes seen as above basic vocational training and other vocational examinations. This applies in particular to individuals who have no experience with VPET systems, which often (but not only[122]) applies to non-Swiss individuals (Abrassart et al., 2017; Cattaneo & Wolter, 2016). Nevertheless, Bolli et al. (2018b) show that the social status of VPET in Switzerland can currently still be regarded as high. For the future, efforts must be undertaken to maintain the high social status of VPET because a poor image or low social status of VPET—as in other, e.g., Anglo-Saxon countries—has a long-term negative impact on the attractiveness of VPET as a whole and, in particular, on highly talented young people and their decision to choose a VET path. This would substantially weaken the practical competences and advanced professional components of the current skill mix in the Swiss economy, which in turn could have serious effects on the system's ability to innovate. A future challenge is therefore the protection of the social status of VET and PET degrees. This is particularly true for VET or PET degrees where empirical evidence shows that they lead to favorable labor market outcomes and attractive career opportunities, but where such evidence is not reflected in a corresponding social status. A strong positioning in favor of VET and PET degrees by the respective industries and the Organizations of the World of Work as well as by companies in their HRM policies (remuneration and career opportunities) will play an important role here.

Switzerland's VPET system must rise to these challenges. For problems that are not yet clear or where causal mechanisms are undetermined, VPET research should be fostered with continuous vigor. Solving the outstanding problems and questions will have a major impact on the innovative capacity of the VPET system, the education system as a whole and the Swiss economy.

employees represent a special case: Although they are aware of the advantages of dual VET, they are often unable to offer apprenticeship places due to their high degree of specialization. The challenge of the sufficient training participation of international companies is therefore, strictly speaking, also a challenge of the specialization of companies. Insofar as domestic companies are also becoming increasingly specialized (e.g., due to outsourcing or the relocation of production abroad), alternative forms of training that specifically address the problem of specialization could become increasingly important. These could be, for example, joint training or inter-company training programs, which therefore gain in importance (Mühlemann, 2014). However, here too there is a considerable need for further research.

[121] For an example, see Google at: https://www.yousty.ch/de-CH/lehrstellen/profile/9648889-informatiker-in-efz-applikationsentwicklung-zurich-zh-google-switzerland-gmbh (22.11.2018).

[122] Among the Swiss, only graduates with a tertiary degree, including teachers, rate the status of VET disproportionately lower than that of general education (Swiss Coordination Centre for Educational Research, 2018: 137).

Appendix 1 – Bibliography

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Appendix 2 – List of abbreviations

AG	Aktiengesellschaft (Limited Company/Stock company)
BBG	Berufsbildungsgesetz (Federal Vocational Education and Training Act)
BIBB	Bundesinstitut für Berufsbildung (Federal Institute for Vocational Education and Training)
CAD	Computer-aided design
CAS	Certificate of Advanced Studies
CHF	Confoederatio Helvetica Franc(s) (Swiss franc(s))
CNC	Computerized Numerical Control
DAS	Diploma of Advances Studies
DC	Direct current (motor)
EBA	Eidgenössisches Berufsattest (Federal Certificate of Vocational Education and Training)
EDK	Eidgenössische Konferenz der kantonalen Erziehungsdirektoren der Schweiz (Swiss Conference of Cantonal Ministers of Education)
EFZ	Eidgenössisches Fähigkeitszeugnis (Federal Diploma of Vocational Education and Training)
FDZ	Forschungsdatenzentrum (Research Data Centre)
FIT	Federal Institutes of Technology
FSO	Federal Statistical Office (Bundesamt für Statistik, Schweiz)
fsQCA	Fuzzy-set qualitative comparative analysis
HEdA	Higher Education Act (Federal Act on Funding and Coordination of the Swiss Higher Education Sector)
HFKG	Hochschulförderungs- und –koordinationsgesetz (Federal Act on Funding and Coordination of the Swiss Higher Education Sector)
HR	Human Resources
HRM	Human resource management
IAB	Institut für Arbeitsmarkt und Berufsforschung (Institute for Employment Research)
IPA	Individuelle praktische Arbeit (Individual Practical Work)
ISCED	International Standard Classification of Education
IT	Information Technology
KOF	Konjunkturforschungsstelle (Swiss Economic Institute)
LABB	Längsschnittanalysen im Bildungsbereich (Longitudinal analyses in the education sector)
LAP	Lehrabschlussprüfung (Final examination of a VET program)
MAS	Master of Advanced Studies
MEM	Maschinen-, Elektro- und Metall (Mechanical and electrical engineering)
MINT	Mathematik, Informatik, Naturwissenschaft und Technik (Mathematics, Informatics, Natural Science and Technology), i.e. STEM (Science, Tecnology, Engineering, Math)
MiVo-HF	Verordnung des WBF über Mindestvorschriften für die Anerkennung von Bildungsgängen und Nachdiplomstudien der höheren Fachschulen (EAER Ordinance on the Minimum Requirements for the Recognition of Study Programs and Continuing Education and Training at Professional Education Institutions)
NOGA	Nomenclature Générale des Activités économiques, General Classification of Economic Activities

OCEAN	Openness, Conscientiousness, Extraversion, Agreeableness, and Neuroticism
OdAs	Organisationen der Arbeit (Organizations of the World of Work)
OPET	Federal Office for Professional Education and Technology (Bundesamt für Berufsbildung und Technologie), predecessor of State Secretariat for Education, Research and Innovation (SERI)
PET	Professional Education and Training
PhD	Doctor of Philosophy
PLCs	Programmable Logic Controllers
R&D	Research and Development
SBA	Statistik der Bildungsabschlüsse (Statistics of Educational Qualifications)
SBBK	Schweizerische Berufsbildungsämter-Konferenz (Swiss Conference of VET Offices)
SEMA	Schweizerischer Verband der Elektromaschinenbauer (Swiss Association of Electrical Engineering Firms)
SERI	State Secretariat for Education, Research and Innovation (Staatssekretariat für Bildung, Forschung und Innovation, SBFI)
SESAM	Soziale Sicherheit und Arbeitsmarkt (Social Protection and Labor Market)
SFIVET	Swiss Federal Institute for Vocational Education and Training (Eidgenössisches Hochschulinstitut für Berufsbildung, EHB)
SKBEQ	Schweizerische Kommission für Berufsentwicklung und Qualität (Committee for occupation development and quality)
SKOBEQ-MEM	Schweizerische Kommission für Berufsentwicklung und Qualität in den Grundbildungen der Maschinen-, Elektro- und Metallindustrie der MEM-Branche (Committee for Occupation Development and Quality in the machinery, electrical and metal industries of the MEM sector)
TREE (data)	Transition from Education to Employment (data)
UAS	University of Applied Sciences
UK	United Kingdom
üK	überbetriebliche Kurse (Inter-company training courses)
UNI	Cantonal university
USA	United States of America
UTE	University of Teacher Education
VET	Vocational Education and Training
VPET	Vocational and Professional Education and Training
VSAS	Verband der Schaltanlagen und Automatik Schweiz (Switchgear and Automation Association Switzerland)
WeBiG	Weiterbildungsgesetz (Continuing Education Act)
Wipo	World Intellectual Property Organization

Appendix 3 – Glossary of terms

In this glossary, we briefly explain to an international readership VPET-specific terms that require additional explanations because they require some background information on national VET institutions and regulations. In general, the explanations refer to the Swiss VPET system, especially where qualifications, certificates, degrees, school types and examination regulations or other such matters are concerned. In some cases, the terms also refer more generally to dual training systems such as those in Germany or Austria.

Academization	Increase in students attending **general** academic education institutions (academic universities) rather than VET programs.
Chief Experts/Chief Expert Committees	Chief Experts are responsible for the organization of Q*ualification Procedures*. The *Qualification Procedures*, of which one part is the practical final examination, evaluate whether the apprentices possess the competences and abilities required in the associated educational regulations. The Qualification Procedures consist of school-based and firm-based examinations. Teams of examiners assess, evaluate and validate competences and employability. The involvement of *chief experts* and examiners in the curriculum update process ensures that experience with the implementation and the success of previous *curricula* is also incorporated into the reforms.
Committee for Occupation Development and Quality (Schweizerische Kommission für Berufsentwicklung und Qualität (SKBEQ)) for "Dental Technicians EFZ"	The committee for occupation development and quality (Schweizerische Kommission für Berufsentwicklung und Qualität (SKBEQ) is responsible for the continuous updating of the occupational curricula. The committee consists of all relevant stakeholder in the respective occupation, including representatives of all relevant actors from all language regions (i.e., employer and employee associations, the SERI, the SKKB and the vocational teaching staff.
Committee for Occupation Development and Quality (SKOBEQ-MEM)	The Committee for Occupation Development and Quality (SKOBEQ-MEM) is responsible for the continuous adaptation of the VET programs in the machinery, electrical and metal industries of the MEM sector. It includes members of employers' associations (*Swissmem*, Swissmechanic, SwissPrecision, "Verband der Schaltanlagen und Automatik Schweiz" VSAS and "Schweizerischer Verband der Elektromaschinenbauer" SEMA), representatives of employee associations/unions (SYNA, UNIA), the state (SERI and SBBK) and the vocational schools.
Committees for Occupation Development and Quality (Kommissionen B&Q)	The committees for occupation development and quality (Kommissionen B&Q) are responsible for the continuous review of VET ordinances and the respective occupational *curricula*. Each commission is made up of representatives of the SERI (in accordance with VET ordinances, BBV 2003, Art. 12, para. 1), the *OdAs*, the cantons and the specialized teaching staff (in accordance with the respective *VET ordinances*).
Curriculum	Under "curriculum", we subsume everything that defines the contents of a VET program. These are the typical competences of an occupation, which are defined in the *VET ordinances* ("Bildungsverordnungen") and the associated detailed VET curricula ("Bildungspläne") as well as in the ordinance on the minimum requirements for the general education part of VET programs.
Federal Diploma of Vocational Education and Training (Eidgenössisches Fähigkeitszeugnis, EFZ)	The Federal Diploma of Vocational Education and Training (Eidgenössisches Fähigkeitszeugnis, EFZ) is the diploma of a three- or four-year VET program (see also EBA, which is the certificate for a two-year VET-program).
Federal Institute of Technology (FIT)	The Federal Institutes of Technology are a part of the Swiss higher education sector (Hochschulsektor). They are federal institutions in contrast to universities, which are cantonal institutions.
Federal PET Diploma Examinations	Federal PET Diploma Examinations are part of Professional Education and Training

	(PET). They are available on a basic and advanced level (Berufsprüfung und höhere Fachprüfung).
Federal Certificate of Vocational Education and Training (Eidgenössisches Berufsattest, EBA)	The Federal Certificate of Vocational Education and Training (Eidgenössisches Berufsattest, EBA) is the certificate for a two-year VET program.
Federal VPET Act (Berufsbildungsgesetz (BBG))	The Federal VPET Act (BBG) and the VET ordinances (BBV) regulate the responsibilities of the actors in the VPET system (federal government, cantons and *Organizations of the World of Work (OdAs))* and the principle of the *VET-partnership*.
General Baccalaureate (Matura)	The general baccalaureate (Matura) is the degree awarded by *baccalaureate-granting high school (Gymnasium)*. It grants general admission to all Swiss universities in almost all fields (exceptions are medical studies and arts).
Gymnasium - Baccalaureate-granting high schools (Gymnasium)	General baccalaureate-granting high school, finishing with a Swiss Matura, which grants general admission to all Swiss universities in almost all fields (the exceptions are, for example, medical studies and arts).
Host Company Training Network (Lehrbetriebsverbund)	A host company training network is a network of companies that collaborate in the training of apprentices. It enables small or specialized companies to participate in the training of apprentices and ensures that apprentices in such companies get a broad training through training company rotation.
Individual Practical Work (IPA)	The individual practical work (IPA) is part of the practical examinations of a VET program.
Inter-Company Training Course (üK)	Inter-company training courses (üKs) represent a third learning location of VET programs in addition to the vocational school and the practical training in companies. They serve to impart basic skills and, above all, innovative content that is not yet generally available in companies. Inter-company training courses include multiple visits over a few days or weeks during which apprentices have support and time to combine theory and practice. As a consequence of the specialization of some companies, inter-company training courses often also fill learning gaps.
Inter-Company Training Center	Inter-company training centers are the locations of inter-company training courses (üKs).
Organization of the World of Work (OdA)	Organizations of the World of Work" (OdA, Organisationen der Arbeit) are associations or organizations from the world of work (labor market) and have legally defined roles in the VPET system that are laid down in the Federal-VPET Act. As a rule, they are nation-wide Organizations of the World of Work, i.e. employers' associations, trade unions and professional associations. However, if there are no such organizations in a particular VET field, the federal government may involve other bodies, e.g. organizations active in a similar VET field or regionally active organizations in the respective VET field, as well as interested cantons. According to SERI (2018), OdAs can be divided into two groups: 1. professional associations and sectoral organizations, 2. VET-partners and other organizations and providers of VPET. In a broad sense, companies - as members of the above mentioned organizations - can also be counted as OdAs (cf. SERI, 2017b).
Passerelle	The “Passerelle: Vocational Baccalaureate to Academic University” is a supplementary examination for *vocational baccalaureate* graduates who plan to study at an academic university. The supplementary examination is offered by the Swiss Baccalaureate Commission and organized by the State Secretariat for Education, Research and Innovation. Together with a *vocational baccalaureate* the supplementary examination grants access to all Swiss universities and all fields of study. The type of preparation for the supplementary examination can be freely chosen by the individual. The preparation can be auto-didactic or by attending a one-year course offered by private or public schools.

PET	Professional Education and Training (PET) (Höhere Berufsbildung) builds on a VET degree and additional professional experience. It consists of two paths: first, Federal PET Diploma Examinations that are available on a basic and an advanced level (Berufsprüfung und höhere Fachprüfung) and second, study programs at PET colleges (Bildungsgänge an höheren Fachschulen). PET in general is competence based and labor market oriented, it focuses on applied learning, on rapid application of novel competences and on a high innovation rhythm.
PET Colleges	PET colleges have been in existence since 2005 and in the meantime have seen a sharp increase in the number of graduates. Compared to the Federal PET Diploma Examinations and the Advanced Federal PET Diploma Examinations, the PET colleges have a more general orientation; compared to the UASs, there is no research, and they are more directly oriented towards the labor market
Qualification Procedure	"Qualification Procedure" is the generic term for all procedures (examinations) used to determine whether a person possesses the required competences laid down in the *VET ordinances* of each occupation. The occupational competencies are proven by one overall final examination, a combination of interim examinations or other Qualification Procedures recognized by the SERI. The most important Qualification Procedure is the final examination at the end of a VETprogram.
Schnupper Lehre/Sniffing Program	A Sniffing Program is an internship for 8th or 9th graders with a length of a week or two, in which the apprentices get to know an occupation and the work at a company and the company gets to know the student.
Specialized Baccalaureate (Fachmaturität)	The specialized baccalaureate (Fachmaturität) is a degree of an *upper secondary specialized school*, which grants admission to *Universities of Applied Sciences (UASs)*.
Swiss Conference of Cantonal Ministers of Education (EDK)	The Swiss Conference of Cantonal Ministers of Education (EDK) is a political body formed by the 26 cantonal ministers of education. The cantons have the main responsibility for education in Switzerland. They coordinate their work at the national level through the EDK. The foundation for the work of the EDK are legally binding intercantonal agreements, known as "concordats" (cf. http://www.edk.ch/dyn/11553.php).
Swiss Conference of VET Offices (SBBK)	Swiss Conference of VET Offices is a political body formed by the 26 cantonal and the Liechtensteinian offices/directors of vocational education, responsible for the intercantonal coordination of vocational education and a special part ("Fachkonferenz") of the EDK. (cf. http://www.sbbk.ch/dyn/19719.php).
Swiss Federal Institute for Vocational Education and Training (SFIVET)	The Swiss Federal Institute for Vocational Education and Training (SFIVET) is a specialized VET higher education institution that offers training for VET professionals and conducts research in VET.
University of Applied Sciences (UAS)	Universities of Applied Sciences (UASs) are part of the Swiss higher education sector. They are formally assigned to the university sector. In contrast to traditional universities, UASs focus on applied research and practically oriented studies. An important part of their mandate is to provide a tertiary level career path for VET graduates.
Upper Secondary Specialized School (Fachmittelschule)	The upper secondary specialized school (Fachmittelschule) is a cantonal school on the upper secondary level, which finishes with an *upper secondary specialized school certificate* and, voluntarily, with a *specialized baccalaureate.*
Upper Secondary Specialized School Certificate (Fachmittelschulabschluss)	The upper secondary specialized school certificate (Fachmittelschulabschluss) is a degree of an *upper secondary specialized school*, which grants admission to PET colleges in the studied field.
VET	VET on the upper secondary level (Berufliche Grundbildung) includes dual

	apprenticeship (company-based) programs and school-based VET programs. Such VET programs are typically 3–4 year programs. Dual apprenticeship programs are the predominant type and consist of two parts: a company part and a school part; approximately 60% to 80% of the time is spent in the training company, and approximately 20% to 40% is spent in a specialized *vocational school*.
VET Curricula (Bildungspläne)	The VET curricula (Bildungspläne) define the contents of VET programs, such as the required competences, the contents taught in the *vocational schools* and contents of the Qualification Procedures.
VET Office (Kantonale Berufsbildungs-ämter)	VET offices are the cantonal authorities responsible for the implementation of the Federal Act on Vocational and Professional Education and Training in the cantons. They are the centers of competence for questions regarding VET in the cantons.
VET Ordinances (“Bildungsverordnungen”)	VET ordinances (“Bildungsverordnungen”) are issued by the federal government and define the legally binding content of VET.
VET-partnership (Verbundpartnerschaft)	In Switzerland VET is a responsibility of the federal government, the cantons and Organizations of the World of Work. These three VET-partners work together in the so-called VET-partnership. Together they are committed to high-quality vocational education and training. In addition, they aim to provide a sufficient number of VET training places in Switzerland. The different tasks of the three VET-partners are clearly defined. The federal government is responsible for strategic control and development, the cantons for implementation and supervision. The Organizations of the World of Work (OdAs) provide VET content and VET training places.
Vocational Baccalaureate (Berufsmaturität)	The vocational baccalaureate (Berufsmaturität) is a degree, which can be obtained during a VET program (additional to the EFZ) or after a VET program and grants access to the universities of applied sciences
Vocational School	Vocational schools are one part of the dual VET programs and teach theoretical vocational and general contents. VET students spend about 60% to 80% in the training company and about 20% to 40% in the vocational school
VPET system	The VPET system consists of *Vocational Education and Training (VET)* on the upper secondary level and of advanced *Professional Education and Training (PET)* on the tertiary level.
VPET Professionals (Berufsbildungsverantwortliche)	VPET professionals are experts who provide workplace training or classroom instruction within the framework of VET programs (BBG, Art 2, Para 1).
VPET-High-Level Meeting (Spitzentreffen der Berufsbildung)	The VPET-High-Level meeting takes place annually. The Federal Councillor invites top representatives from the federal government, cantons, politics and business to discuss current issues and challenges in VPET. The annual meeting is dedicated to political and strategic exchange. The agenda items are jointly planned by the VPET-partners . Approved projects are implemented jointly.
VPET-Partnership-Conference (Verbundpartnertagung)	The VPET-partnership-conference takes place once a year. Participants from the federal government, cantons and O*rganizations of the World* of Work meet to jointly develop vocational education and training in Switzerland. The VPET-partnership-conference is a work meeting and offers a platform to jointly deal with a defined *VPET* issue in depth.

Appendix 4 – Translations of general and Vocational Education and Training terminology used in this report

German	**English**

Bildungseinrichtungen/ Schulen/ Hochschulen	**Educational Institutions/ Schools/ Colleges/ Universities**
Ausbildungsverbund	Host company training networks (BBG)
Berufsschule	Vocational Schools
Fachhochschulen	Universities of Applied Sciences
Gymnasium	Baccalaureate School, oder Baccalaureate Granting High Schools
Höhere Fachschulen	PET colleges
Pädagogische Hochschulen	Universities of Teacher Education
Überbetriebliche Kurse / *Kurszentren*	inter-company training courses / course centers
Universitäten, *Eidgenössische Hochschulen*	Academic Universities, Federal Institutes of Technology

VPET Terminology	**VPET Terminologie**
Ausbildungsplan	VET curriculum
Ausbildungsplätze	VET training places in firms Apprenticeship places in firms
Ausbildungsverordnung	VET ordinance
Basisausbildung (innerhalb einer Berufslehre)	Basic (vocational) training
Berufliche Grundbildung	VET (Vocational Education and Training)
Berufliche Handlungskompetenzen	Occupational competencies, also: professional competencies (more general competencies not necessarily related to a particular occupation)
Berufliche Weiterbildung	Continuing VPET
Berufsbild	Occupational profile (description of content of a particular VET program, contained in the VET curriculum; e.g. main activities, etc.)
Berufsbildner	VPET trainer
Berufsbildung (auf Sek-II- und auf tertiärer Stufe)	VPET: Vocational and Professional Education and Training on secondary or tertiary level
Berufslehre (z.B. als Chemielaborant)	VET program (e.g. Chemical Laboratory Technician)
Berufslernende	Apprentice (Betrieb), VET student (Schulisch)
Betriebliche Bildung	Company-based VET
Höhere Berufsbildung	PET (Professional Education and Training)
Höherqualifizierung	Educational upgrading, upgrading of skills
Schulische Bildung	School-based education (VET)
Schwerpunktausbildung (innerhalb einer Berufslehre)	VET program - Specialization track
Weiterbildung (als Ganzes, d.h. formal, non-formal, informell;	Continuing education and training (in general, i.e. formal,

beruflich und akademisch)	non-formal, informal; vocational and academic)

Abschlüsse/Zertifikate/ Prüfungen und Prüfungsexperten	**Degrees/certificates/ examinations and examiners**
Berufsmatur	Vocational baccalaureate
Chefexperte *Oberaufsicht/Hauptdelegierte der Prüfungsexperten*	Leading examination expert Supervisors/Main Delegates of the Examination Experts
Matura, *Maturand*	General baccalaureate, General baccalaureate graduate
Eidgenössisches Berufsattest	Federal VET certificate / Federal Certificate of VET
Eidgenössisches Fähigkeitszeugnis EFZ, *Lehrabschluss*	Federal VET diploma (EFZ) / Federal Diploma of VET, VET degree (Lehrabschluss)
Prüfungen der höheren Berufsbildung	PET examinations
Berufsprüfungen, Eidgenössische Berufsprüfungen	Federal PET diploma examinations
Höhere Fachprüfungen	Advanced Federal PET diploma examinations
Höhere Fachschuldiplome	PET college diploma
Prüfungsexperten	Examination experts (for interim or final examinations of VET programs)

Akteure/ ***Institutionen der Berufsbildung/*** ***Prozesse***	**Actors /** **Institutions involved in VPET /** **Processes**
Berufsentwicklungsanalyse	Occupational development analysis
Berufskenntnisprüfung	Occupational competence examination
Berufsreform (i.e., Berufsentwicklungsprozess)	curriculum update process
Kommission für Berufsentwicklung und Qualität	Committees for Occupation Development and Quality (CODQ)
Qualifikationsprofil der beruflichen Grundbildung	Qualification profile of a VET program
Qualifikationsverfahren	Qualification procedure
Schweizerische Berufsbildungsämter-Konferenz	Swiss Conference of VET Education Offices
Tätigkeitsprofil	Activity profile
Verbandsübergreifende Arbeitsgruppe (bestehend aus Berufspraktikern und –experten, zur Erstellung der neuen Bildungspläne und Bildungsverordnungen)	Inter-association working group (consisting of occupational practitioners and experts, for the development of new educational curricula and ordinances)
Verbundpartnerschaft	VET partnership
Verbundpartnertagungen	VET partnership-conferences

Berufe	**VET Programs**
Anlagen- und Apparatebauer EFZ	Apparatus Engineer EFZ
Automatiker EFZ	Automation Engineer EFZ
Automatikmonteur EFZ	Automation Technician EFZ
Automationsmonteur EFZ	Automation Fitters EFZ
Biologielaborant EFZ	Biological Laboratory Technician EFZ
Büroassistenz EBA	Office Assistant EBA
Chemie- und Pharmatechnologe EFZ	Chemical and Pharmaceutical Process Technologist EFZ

Chemielaborant EFZ	Chemical Laboratory Technician EFZ
Elektroniker EFZ	Electronics Engineer EFZ
Gusstechnologe EFZ	Casting Technologist EFZ
Industrielackierer EFZ	Industrial Varnisher EFZ
Informatiker EFZ	Information Technologist EFZ
Konstrukteur EFZ	Design Engineer EFZ
KV EFZ	Commercial Employee EFZ
Logistiker EFZ	Logistics Technician EFZ
Mechanikpraktiker EBA	Mechanical Assistant EBA
Polymechaniker EFZ	Polymechanic EFZ
Produktionsmechaniker EFZ	Mechanical Technician EFZ
Zahntechniker EFZ	Dental Technician EFZ

English	***German***

Educational Institutions/ Schools/ Colleges/ Universities	***Bildungseinrichtungen/ Schulen/ Hochschulen***
Academic Universities (UNIs), Federal Institutes of Technology (FITs)	*Universitäten,* *Eidgenössische Hochschulen*
Baccalaureate School, oder Baccalaureate Granting High Schools	*Gymnasium*
Host company training networks (BBG)	*Ausbildungsverbund*
inter-company training courses / course centers	*Überbetriebliche Kurse /* *Kurszentren*
PET colleges	*Höhere Fachschulen*
Universities of Applied Sciences	*Fachhochschulen*
Universities of Teacher Education	*Pädagogische Hochschulen*
Vocational Schools	*Berufsschule*

VPET Terminologie	***VPET Terminology***
Apprentice (Betrieb), VET student (Schulisch)	*Berufslernende (betriebliche Berufsbildung, vollschulische Berufsbildung)*
Basic (vocational) training	*Basisausbildung (innerhalb einer Berufslehre)*
Company-based VET	*Betriebliche Bildung*
Continuing education and training (in general, i.e. formal, non-formal, informal; vocational and academic)	*Weiterbildung (als Ganzes, d.h. formal, non-formal, informell; beruflich und akademisch)*
Continuing VPET	*Berufliche Weiterbildung*
Educational upgrading, upgrading of skills	*Höherqualifizierung*
Occupational competencies, also: professional competencies (more general competencies not necessarily related to a particular occupation)	*Berufliche Handlungskompetenzen*
Occupational profile (description of content of a particular VET program, contained in the VET curriculum; e.g. main activities, etc.)	*Berufsbild*
PET (Professional Education and Training)	*Höhere Berufsbildung*
School-based education (VET)	*Schulische Bildung*
VET (Vocational Education and Training)	*Berufliche Grundbildung*
VET curriculum	*Ausbildungsplan*
VET ordinance	*Ausbildungsverordnung*
VET program - Specialization track	*Schwerpunktausbildung (innerhalb einer Berufslehre)*
VET program (e.g. Chemical Laboratory Technician)	*Berufslehre (z.B. als Chemielaborant)*
VET training places in firms Apprenticeship places in firms	*Ausbildungsplätze*
VPET trainer	*Berufsbildner*
VPET: Vocational and Professional Education and Training on secondary or tertiary level	*Berufsbildung (auf Sek-II- und auf tertiärer Stufe)*

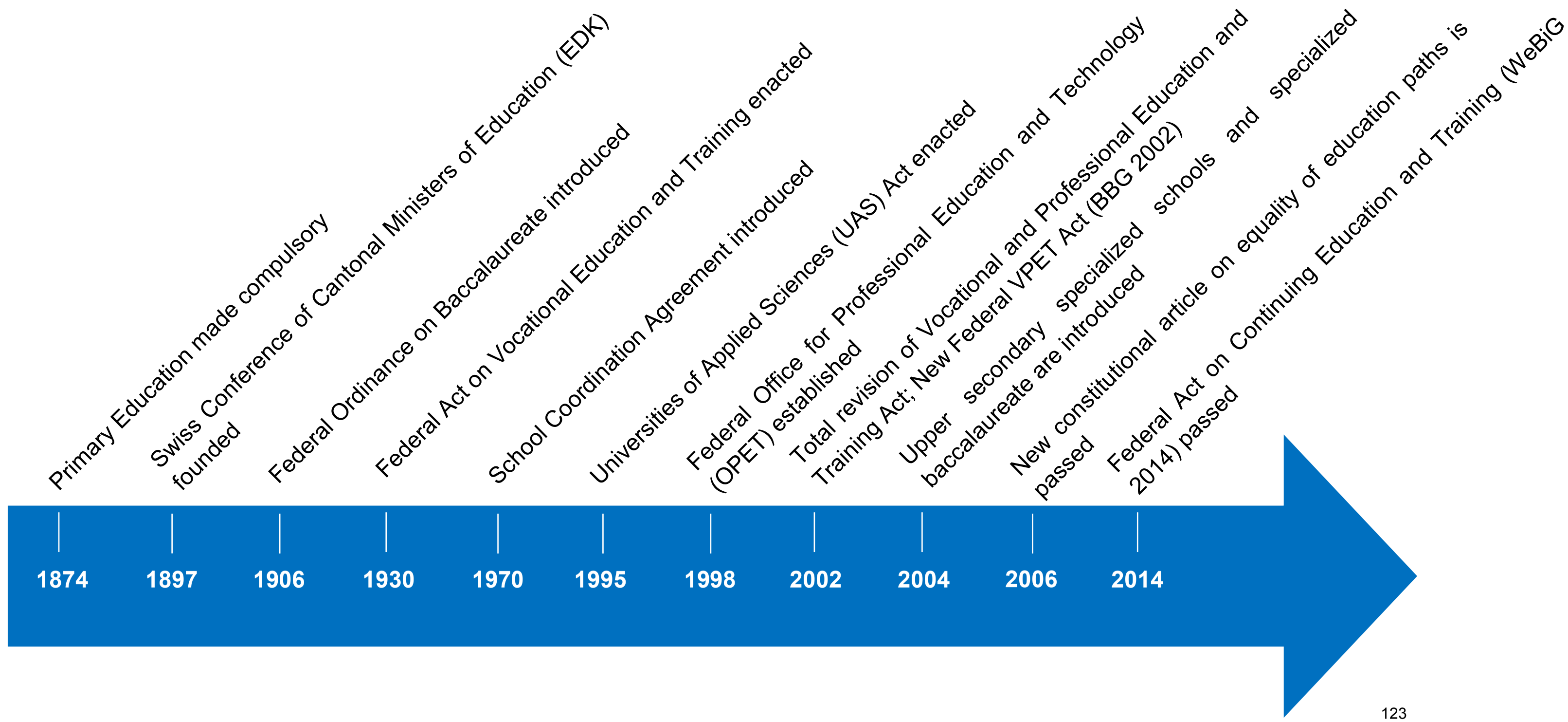
Degrees/certificates/ examinations and examiners	***Abschlüsse/Zertifikate/ Prüfungen und Prüfungsexperten***
Advanced Federal PET diploma examinations	*Höhere Fachprüfungen*
Examination experts (for interim or final examinations of VET programs)	*Prüfungsexperten*
Federal PET diploma examinations	*Berufsprüfungen, Eidgenössische Berufsprüfungen*
Federal VET certificate / Federal Certificate of VET	*Eidgenössisches Berufsattest*
Federal VET diploma (EFZ) / Federal Diploma of VET, VET degree (Lehrabschluss)	*Eidgenössisches Fähigkeitszeugnis EFZ, Lehrabschluss*
General baccalaureate, General baccalaureate graduate	*Matura, Maturand*
Leading examination expert Supervisors/Main Delegates of the Examination Experts	*Chefexperte Oberaufsicht/Hauptdelegierte der Prüfungsexperten*
PET college diploma	*Höhere Fachschuldiplome*
PET examinations	*Prüfungen der höheren Berufsbildung*
Vocational baccalaureate	*Berufsmatur*

Actors / Institutions involved in VPET / Processes	***Akteure/ Institutionen der Berufsbildung/ Prozesse***
Activity profile	*Tätigkeitsprofil*
Committees for Occupation Development and Quality (CODQ)	*Kommission für Berufsentwicklung und Qualität*
curriculum update process	*Berufsreform (i.e., Berufsentwicklungsprozess)*
Inter-association working group (consisting of occupational practitioners and experts, for the development of new educational curricula and ordinances)	*Verbandsübergreifende Arbeitsgruppe (bestehend aus Berufspraktikern und –experten, zur Erstellung der neuen Bildungspläne und Bildungsverordnungen)*
Occupational competence examination	*Berufskenntnisprüfung*
Occupational development analysis	*Berufsentwicklungsanalyse*
Qualification procedure	*Qualifikationsverfahren*
Qualification profile of a VET program	*Qualifikationsprofil der beruflichen Grundbildung*
Swiss Conference of VET Education Offices	*Schweizerische Berufsbildungsämter-Konferenz*
VET partnership	*Verbundpartnerschaft*
VET partnership-conferences	*Verbundpartnertagungen*

VET Programs	***Berufe***
Apparatus Engineer EFZ	*Anlagen- und Apparatebauer EFZ*
Automation Engineer EFZ	*Automatiker EFZ*
Automation Fitters EFZ	*Automationsmonteur EFZ*
Automation Technician EFZ	*Automatikmonteur EFZ*
Biological Laboratory Technician EFZ	*Biologielaborant EFZ*
Casting Technologist EFZ	*Gusstechnologe EFZ*
Chemical and Pharmaceutical Process Technologist EFZ	*Chemie- und Pharmatechnologe EFZ*
Chemical Laboratory Technician EFZ	*Chemielaborant EFZ*
Commercial Employee EFZ	*KV EFZ*

Dental Technician EFZ	*Zahntechniker EFZ*
Design Engineer EFZ	*Konstrukteur EFZ*
Electronics Engineer EFZ	*Elektroniker EFZ*
Industrial Varnisher EFZ	*Industrielackierer EFZ*
Information Technologist EFZ	*Informatiker EFZ*
Logistics Technician EFZ	*Logistiker EFZ*
Mechanical Assistant EBA	*Mechanikpraktiker EBA*
Mechanical Technician EFZ	*Produktionsmechaniker EFZ*
Office Assistant EBA	*Büroassistenz EBA*
Polymechanic EFZ	*Polymechaniker EFZ*

Appendix 5 – Selected timeline on education, research and innovation in Switzerland



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[123] Excerpts from Table "Education, Research and Innovation in Switzerland: Timeline" (Updated: April 2018), cf. https://www.sbfi.admin.ch/dam/sbfi/en/dokumente/2016/06/chronologie-f-i.pdf.download.pdf/chronologie_e.pdf