Exploratory study
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Digital competences

Paper commissioned by the Swiss Science and Innovation Council SSIC

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Professor Sabine Seufert, University of St. Gallen

With an introductory comment by Professor Alexander Repenning, University of Applied Sciences and Arts Northwestern Switzerland and University of Colorado

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Conseil suisse de la science et de l'innovation
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Swiss Science and Innovation Council

The present publication is an excerpt of the third chapter from the forthcoming SSIC publication "Notions of disruption" (Exploratory study 3/2017)

The Swiss Science and Innovation Council

The Swiss Science and Innovation Council SSIC is the advisory body to the Federal Council for issues related to science, higher education, research and innovation policy. The goal of the SSIC, in conformity with its role as an independent consultative body, is to promote the framework for the successful development of the Swiss higher education, research and innovation system. As an independent advisory body to the Federal Council, the SSIC pursues the Swiss higher education, research and innovation landscape from a long-term perspective.

Der Schweizerische Wissenschafts- und Innovationsrat

Der Schweizerische Wissenschafts- und Innovationsrat SWIR berät den Bund in allen Fragen der Wissenschafts-, Hochschul-, Forschungs- und Innovationspolitik. Ziel seiner Arbeit ist die kontinuierliche Optimierung der Rahmenbedingungen für die gedeihliche Entwicklung der Schweizer Bildungs-, Forschungs- und Innovationslandschaft. Als unabhängiges Beratungsorgan des Bundesrates nimmt der SWIR eine Langzeitperspektive auf das gesamte BFI-System ein.

Le Conseil suisse de la science et de l'innovation

Le Conseil suisse de la science et de l'innovation CSSI est l'organe consultatif du Conseil fédéral pour les questions relevant de la politique de la science, des hautes écoles, de la recherche et de l'innovation. Le but de son travail est l'amélioration constante des conditions-cadre de l'espace suisse de la formation, de la recherche et de l'innovation en vue de son développement optimal. En tant qu'organe consultatif indépendant, le CSSI prend position dans une perspective à long terme sur le système suisse de formation, de recherche et d'innovation.

Il Consiglio svizzero della scienza e dell'innovazione

Il Consiglio svizzero della scienza e dell'innovazione CSSI è l'organo consultivo del Consiglio federale per le questioni riguardanti la politica in materia di scienza, scuole universitarie, ricerca e innovazione. L'obiettivo del suo lavoro è migliorare le condizioni quadro per lo spazio svizzero della formazione, della ricerca e dell'innovazione affinché possa svilupparsi in modo armonioso. In qualità di organo consultivo indipendente del Consiglio federale il CSSI guarda al sistema svizzero della formazione, della ricerca e dell'innovazione in una prospettiva globale e a lungo termine.

Preface by the SSIC

This collection of papers is the result of the exploratory phase of the SSIC's work on the overarching theme of "disruptive change in economy and society by technology and other drivers" from its 2016–2019 Working Programme.[1] During the past few months, the SSIC has committed itself to exploring the notion of disruptive innovation in one of its plenary and in several working-group meetings. With the publication of this collection, the SSIC is pleased to make the results of its exploratory work available to interested readers.

As a first step, the Council decided to compile a definitory discussion based on Christensen's (2000) notion of disruptive innovation. This critical discussion also includes the approach of Henderson and Clark (1990) as well as Gans' (2016) effort to unify the two notions of disruptive innovation. This paper further contains an analysis of the Swiss education, research, and innovation (ERI) landscape and how its actors can influence the emergence of disruptive innovations and how they at the same time are affected by it. In addition, Council members have identified key issues in their November 2016 plenary meeting with regard to the Swiss ERI landscape.

As a second step, the process of digitalisation (including its underlying potentially disruptive technological innovations and business models) was chosen as an illustrative example. The example lends itself to illustration for two reasons: First, it is of high relevance to the Swiss economy, characterised by its high level of technological development and lack of natural resources. Second, because both firms and the labour force are affected by digitalisation, the case is of direct relevance to the Swiss ERI system (with education in particular) and thus the SSIC's field of expertise. In order to better understand how potentially disruptive innovations affect the economy and society, the Council has invited Vivek Wadhwa, professor at Carnegie Mellon University's College of Engineering, to address the SSIC at its November 2016 plenary meeting. A short summary of his keynote speech is presented here in the second paper and the corresponding transcript may be found in the respective appendix.

Finally, the Council was interested in how digitalisation challenges the education system. The SSIC therefore invited Sabine Seufert, professor for Business Education at the University of St. Gallen, to give a keynote speech at its November 2016 plenary meeting. Due to her absence owing to illness, she has been mandated to formulate her considerations on digital competences in a short position paper. At the invitation of the Council's working group, Alexander Repenning, professor for Computer Science Education at the University of Applied Sciences FHNW and the University of Colorado, wrote an introductory comment to this collection's third and final paper. In his comment, he embeds professor Seufert's position paper in the Swiss education system, provides an international comparison, and supplies concrete action items.

Based on these exploratory studies, the Council will continue to examine the effects of potentially disruptive technologies on different Swiss business sectors and society. In exploring how incumbent businesses and start-ups deal with uncertainty, the Council intends to focus on the role of the ERI system's actors in exploiting the positive effects of disruptive innovations and mitigating its negative effects on businesses and society.

1 http://swir.ch/en/programme

Vorwort des SWIR

Diese Sammlung von Arbeiten ist das Resultat der explorativen Studien des SWIR zum übergreifenden Thema «Disruptive Veränderungen in Wirtschaft und Gesellschaft durch Technologie und andere Faktoren» gemäss dem Arbeitsprogramm 2016–2019[2]. In den letzten Monaten beschäftigte sich der SWIR in einer seiner Plenarversammlungen und in mehreren Arbeitsgruppentreffen mit dem Begriff der disruptiven Innovation. Gerne stellt der SWIR nun mit der Veröffentlichung dieser Sammlung die Resultate seiner explorativen Arbeit einer interessierten Leserschaft zur Verfügung.

Als Erstes entschied sich der Rat für eine definitorische Eingrenzung gestützt auf den Begriff der disruptiven Innovation von Christensen (2000). Ausserdem wurden auch der Ansatz von Henderson und Clark (1990) sowie die Bestrebungen von Gans (2016) zur Vereinheitlichung der beiden Definitionen der disruptiven Innovation kritisch betrachtet. Diese Arbeit enthält zudem eine Analyse der schweizerischen Bildungs-, Forschungs- und Innovationslandschaft (BFI-Landschaft) und untersucht, wie deren Akteure disruptive Innovationen einerseits beeinflussen können und andererseits auch davon betroffen sind. Überdies bestimmten die Ratsmitglieder in der Plenarversammlung vom November 2016 Kernthemen betreffend die Schweizer BFI-Landschaft.

Als Zweites wurde der Prozess der Digitalisierung (einschliesslich der diesem zugrundeliegenden potenziell disruptiven technologischen Innovationen und Geschäftsmodelle) als anschauliches Beispiel gewählt. Das Thema eignet sich aus zwei Gründen zur Veranschaulichung: Erstens ist es von grosser Relevanz für die Schweizer Wirtschaft, die durch einen hohen technologischen Entwicklungsgrad und fehlende natürliche Ressourcen geprägt ist. Zweitens sind sowohl die Arbeitgeber als auch die Arbeitnehmenden von der Digitalisierung betroffen, weshalb das Beispiel für das BFI-System (insbesondere die Bildung) unmittelbar von Bedeutung ist und somit in den Fachbereich des SWIR fällt. Um besser zu verstehen, wie potenziell disruptive Innovationen die Wirtschaft und die Gesellschaft beeinflussen, lud der Rat Vivek Wadhwa, Professor des Carnegie Mellon University's College of Engineering, als Redner an die Plenarsitzung des SWIR vom November 2016 ein. Der zweite Beitrag enthält eine kurze Zusammenfassung seines Vortrags und das entsprechende Transkript ist im Anhang zu finden.

Schliesslich befasste sich der Rat mit den Herausforderungen, die die Digitalisierung für das Bildungssystem mit sich bringt. Dazu lud er Sabine Seufert, Professorin für Wirtschaftspädagogik der Universität St. Gallen, für einen Vortrag an die Plenarversammlung vom November 2016 ein. Aufgrund ihrer krankheitsbedingten Abwesenheit wurde sie gebeten, ihre Ansichten zu digitalen Kompetenzen in einem kurzen Positionspapier festzuhalten. Alexander Repenning, Professor für Informatische Bildung der Fachhochschule Nordwestschweiz FHNW und der Universität von Colorado, verfasste auf Einladung der Arbeitsgruppe des Rates einen einleitenden Kommentar zum dritten und letzten Beitrag der Sammlung. Darin bettet er das Positionspapier von Professorin Seufert in das Schweizer Bildungssystem ein, zieht einen internationalen Vergleich und zeigt konkrete Handlungsfelder auf.

Ausgehend von diesen explorativen Studien wird der Rat die Auswirkungen potenziell disruptiver Technologien auf verschiedene Industrien und die Schweizer Gesellschaft weiter erforschen. Bei seiner Untersuchung, wie etablierte Unternehmen und Start-ups mit Unsicherheit umgehen, will sich der Rat auf die Rolle der BFI-Akteure bei der Nutzung der positiven Effekte und bei der Milderung der negativen Auswirkungen disruptiver Innovationen auf die Wirtschaft und die Gesellschaft konzentrieren.

2 http://swir.ch/de/arbeitsprogramm

Préface du CSSI

Ce recueil de rapports est le résultat de la phase exploratoire du travail du CSSI sur la thématique globale des «changements disruptifs dans l'économie et la société induits par les technologies et par d'autres facteurs» de son programme de travail 2016–2019[3]. Au cours des derniers mois, le CSSI s'est consacré à l'exploration de la notion d'«innovation disruptive» lors de l'une de ses séances plénières et de plusieurs réunions de son groupe de travail. Avec la publication de ce recueil, le CSSI est ravi de pouvoir faire partager aux lecteurs intéressés le résultat de son travail d'exploration.

Premièrement, le conseil a décidé de mener une discussion définitionnelle en s'appuyant sur la notion d'«innovation disruptive» de Christensen (2000). Cette réflexion critique inclut également l'approche de Henderson et Clark (1990), ainsi que l'effort entrepris par Gans (2016) pour unifier les deux notions d'«innovation disruptive». Ce rapport comprend en outre une analyse du paysage suisse de la formation, de la recherche et de l'innovation (FRI), et de la manière avec laquelle ses acteurs peuvent influencer l'émergence d'innovations disruptives et comment celles-ci les touchent simultanément. Lors de leur séance plénière de novembre 2016, les membres du conseil ont également identifié des questions clés à propos du paysage FRI suisse.

Deuxièmement, l'exemple représentatif choisi est le processus de numérisation (y compris ses innovations technologiques potentiellement disruptives et ses modèles d'affaires). L'exemple se prête bien à la démonstration pour deux raisons: il revêt tout d'abord une grande importance pour l'économie suisse, qui est caractérisée par son niveau élevé de développement technologique et son manque de ressources naturelles. Ensuite, étant donné que les entreprises et la population active sont touchées par la numérisation, le cas concerne directement le système FRI suisse (la formation en particulier), qui est le domaine de compétence du CSSI. Pour mieux comprendre à quel point les innovations potentiellement disruptives touchent l'économie et la société, le conseil a invité Vivek Wadhwa, professeur au Carnegie Mellon University's College of Engineering, à prononcer un discours lors de la séance plénière du CSSI en novembre 2016. Un bref résumé de son discours liminaire est présenté dans ce second rapport, et la transcription correspondante se trouve dans l'annexe respective.

Enfin, le conseil s'est intéressé aux défis que pose la numérisation au système de formation. Le CSSI a donc invité Sabine Seufert, professeure de la chaire de Business Education à l'Université de Saint-Gall, à prononcer un discours liminaire lors de sa séance plénière de novembre 2016. N'ayant pas pu y participer pour cause de maladie, il lui a été demandé de formuler ses considérations sur les compétences numériques dans une brève prise de position. A l'invitation du groupe de travail du conseil, Alexander Repenning, professeur de la chaire de Computer Science Education à l'Université des sciences appliquées du Nord-Ouest de la Suisse (FHNW) et à la University of Colorado, a rédigé une introduction au troisième et dernier rapport de ce recueil. Dans son commentaire, il intègre la prise de position de la professeure Seufert dans le système de formation suisse, dresse une comparaison internationale et propose des mesures concrètes.

Sur la base de ces études exploratoires, le conseil continuera à examiner les effets des technologies potentiellement disruptives sur différents secteurs d'activité et la société suisse. En explorant la manière dont les entreprises et les start-up titulaires font face à l'incertitude, le conseil entend se concentrer sur le rôle des acteurs du système FRI en exploitant les effets positifs des innovations disruptives et en compensant ses répercussions négatives sur les entreprises et la société.

3 http://swir.ch/fr/programme-de-travail

Prefazione del CSSI

Questa raccolta di articoli è frutto della fase preliminare del lavoro del CSSI sul vasto tema dei «cambiamenti disrumpenti nell'economia e nella società indotti da nuove tecnologie ed altri fattori», contenuto nel programma di lavoro 2016–2019.[4] Nel corso degli ultimi mesi il CSSI ha analizzato il concetto di innovazione rivoluzionaria in una delle sedute plenarie e in diverse riunioni del gruppo di lavoro. Con la pubblicazione della raccolta vengono messi a disposizione dei lettori interessati i risultati di questo lavoro preliminare.

In una prima fase il Consiglio ha deciso di porre le basi della discussione, avvalendosi della nozione di innovazione rivoluzionaria di Christensen (2000) e tenendo conto dell'approccio di Henderson e Clark (1990) e del tentativo di Gans (2016) di unificare le due definizioni di tale concetto. Il documento contiene inoltre un'analisi del sistema svizzero ERI (educazione, ricerca e innovazione) e illustra come gli operatori possono influenzare ed essere al contempo influenzati dalla comparsa di innovazioni radicali. A novembre 2016, in occasione della seduta plenaria, i membri del Consiglio hanno individuato alcune questioni essenziali riguardanti questo sistema.

In una seconda fase il processo di digitalizzazione (insieme alle innovazioni tecnologiche potenzialmente rivoluzionarie su cui si fonda e ai modelli imprenditoriali) è stato scelto come esempio illustrativo: innanzitutto in quanto di estrema importanza per l'economia svizzera, notoriamente caratterizzata da elevato livello di sviluppo tecnologico e scarsità di risorse naturali, ma anche perché la digitalizzazione influisce su aziende e forza lavoro e quindi interessa direttamente il sistema ERI (in particolare l'educazione) e il settore di competenza del CSSI. Per una migliore comprensione dell'effetto delle innovazioni potenzialmente rivoluzionarie sull'economia e sulla società, il Consiglio ha invitato a parlare alla sessione plenaria di novembre 2016 Vivek Wadhwa, professore presso la facoltà di ingegneria della Carnegie Mellon University. Il secondo articolo contiene un breve riassunto del suo discorso e in appendice la relativa trascrizione.

Al fine di approfondire il tema delle sfide della digitalizzazione per il sistema educativo, il CSSI ha invitato Sabine Seufert, prof.ssa di pedagogia economica presso l'Università di San Gallo, a tenere un discorso alla seduta plenaria di novembre 2016. A causa della sua assenza per malattia, le è stato richiesto di esporre le proprie considerazioni sulle competenze digitali in un breve documento di sintesi. Su invito del gruppo di lavoro del Consiglio, Alexander Repenning, professore informatica presso l'Università di scienze applicate FHNW e l'Università del Colorado, ha scritto un commento introduttivo al terzo e ultimo articolo di questa raccolta, in cui inquadra le considerazioni della prof.ssa Seufert nel sistema educativo svizzero, fa un confronto a livello internazionale e fornisce proposte di azione concrete.

Sulla base di questi studi preliminari, il Consiglio continuerà a esaminare gli effetti delle tecnologie potenzialmente rivoluzionarie sui diversi settori e sulla società in Svizzera. Analizzando il modo in cui le aziende e le start-up gestiscono l'incertezza, il Consiglio intende concentrarsi sul ruolo degli operatori ERI nello sfruttamento degli effetti positivi delle innovazioni rivoluzionarie e nell'attenuazione degli effetti negativi sulle imprese e sulla società.

4 http://swir.ch/it/programma-di-lavoro

Digital competences

Among the many effects digitalisation will have on our way of working and living, the augmentation of human skills through machines is the most central. The current debate should therefore not focus on the substitution of human workforce.

To understand how humans and in the end society interact with machines, Professor Seufert presents a framework proposed by MIT Associate Professor Iyad Rahwan: Moving from a simple "human-in-the-loop" (formulating goals, constraints, expectations, etc., for machines to perform tasks) towards a "society-in-the-loop". This refers to the embedding of ethical values, laws, and social norms into the way autonomous systems (artificial intelligence, etc.) perform their tasks.

To accomplish a well-performing human- and society-in-the-loop, digital competences are necessary. These competences should be established as transversal competences into the education system based on a "spiral curriculum" framework. Digital competences consist of digital literacy, digital citizenship, and finally the development of personality in a digital society. Current empirical results with regard to digital competences of students are alarming – especially given the current lack of a national digital competence framework in Switzerland:

- In terms of computer and information literacy, Swiss students do not exhibit above average competences in comparison to other EU countries and almost 30% do not exceed the lowest level of competence.
- There is some evidence that Swiss students have deficits particularly in information literacy.
- Data supports the existence of a socio-economic and gender gap in digital skills.
- Although students are digital natives, they lack sufficient Internet skills.
- Students' objective literacy is considerably lower than their subjective self-assessed literacy.
- Due to a very low response rate, no analysis of teacher competences from the ICILS 2013 study is publicly available for Switzerland.

Professor Seufert concludes her paper with six points: 1. Raising awareness for complementary competences; 2. Development of a national digital competence framework; 3. Establishment of formative assessments, integrated assessment systems and a graduation portfolio system; 4. Enabling do-it-yourself learning in educational institutions; 5. Capacity building through the development of digital competences of teachers; 6. Further research in the field of digital competences to close the society-in-the-loop gap.

Digitale Kompetenzen

Bei den zahlreichen Auswirkungen, die die Digitalisierung auf unsere Arbeits- und Lebensweise haben wird, steht die Erweiterung der menschlichen Fähigkeiten durch Maschinen an erster Stelle. Die aktuelle Debatte sollte sich deshalb nicht auf den Ersatz der menschlichen Arbeitskraft fokussieren.

Um zu verstehen, wie der Mensch und letztlich die Gesellschaft mit Maschinen interagieren, stellt Professorin Seufert ein Rahmenwerk von Iyad Rahwan, ausserordentlicher Professor am MIT, vor: Die Entwicklung geht vom einfachen «Mensch in der Schleife» («human-in-the-loop»: Formulierung von Zielen, Vorgaben, Erwartungen etc. für Maschinen, die Aufgaben ausführen sollen) in Richtung einer «Gesellschaft in der Schleife» («society-in-the-loop»). Gemeint ist hier der Einbezug von ethischen Werten, Gesetzen und sozialen Normen in die Art, wie autonome Systeme (künstliche Intelligenz etc.) ihre Aufgaben erledigen.

Für ein leistungsfähiges Mensch- oder Gesellschaft-in-der-Schleife-System sind digitale Kompetenzen gefordert. Diese Kompetenzen sollten als fachübergreifende Kompetenzen in das Bildungssystem aufgenommen werden, und zwar mithilfe eines Spiralcurriculums. Digitale Kompetenz besteht aus digitalen Kenntnissen, digitaler Bürgerschaft und schliesslich der Persönlichkeitsentwicklung in einer digitalen Gesellschaft.

Aktuelle empirische Resultate zur digitalen Kompetenz von Schülerinnen und Schülern sind alarmierend – insbesondere da in der Schweiz ein nationaler Rahmenlehrplan für digitale Kompetenz momentan fehlt:

- Bei den Computer- und Informatikkenntnissen schneiden die Schweizer Schülerinnen und Schüler im Vergleich zu anderen EU-Ländern lediglich durchschnittlich ab, und fast 30 % von ihnen kommen nicht über die tiefste Kompetenzstufe hinaus.
- Es gibt Hinweise darauf, dass Schweizer Schülerinnen und Schüler insbesondere in der Informatikbildung Lücken aufweisen.
- In Bezug auf digitale Kenntnisse scheinen sozioökonomische und geschlechterbezogene Ungleichheiten zu existieren.
- Obwohl die Schülerinnen und Schüler «Digital Natives» sind, mangelt es ihnen an ausreichenden Internetkenntnissen.
- Die objektive Kompetenz der Schülerinnen und Schüler ist deutlich tiefer als die von ihnen selbst subjektiv wahrgenommene Kompetenz.
- Aufgrund einer sehr tiefen Rücklaufquote ist für die Schweiz keine Analyse der Kompetenzen von Lehrpersonen aus der Studie ICILS 2013 öffentlich verfügbar.

Professorin Seufert stellt am Ende ihres Positionspapiers sechs Forderungen in den Raum: 1. Das Bewusstsein für ergänzende Kompetenzen stärken; 2. Einen nationalen Rahmenlehrplan für digitale Kompetenz entwickeln; 3. Formative Beurteilungen, integrierte Beurteilungssysteme und «Graduation Portfolio»-Systeme einführen; 4. Do-it-yourself-Lernen in Bildungsinstitutionen ermöglichen; 5. Durch die Entwicklung von digitaler Kompetenz bei den Lehrpersonen Kapazitäten aufbauen; 6. Forschung zu digitaler Kompetenz vertiefen, um die Kluft zur «Gesellschaft in der Schleife» zu schliessen.

Compétences numériques

L'augmentation des compétences humaines via des machines est l'effet principal parmi tous ceux que la numérisation aura sur notre manière de travailler et de vivre. Le débat actuel ne devrait donc pas se concentrer sur la substitution de la main-d'œuvre humaine.

Afin de comprendre comment les humains, et en fin de compte la société, interagissent avec les machines, la professeure Seufert présente un cadre proposé par Iyad Rahwan, professeur associé au MIT: passer du simple «humain dans la boucle» (formulation d'objectifs, de contraintes, d'attentes, etc. pour que les machines réalisent des tâches) à une «société dans la boucle». Cela concerne l'intégration de valeurs éthiques, de lois et de normes sociales dans la manière dont les systèmes autonomes (intelligence artificielle, etc.) réalisent leurs tâches.

Il est nécessaire de disposer de compétences numériques pour réaliser un modèle d'humain et de société dans la boucle performant. Celles-ci doivent être établies comme des compétences transversales dans le système éducatif sur la base d'un cadre de «programme en spirale». Les compétences numériques englobent la maîtrise du numérique, la citoyenneté numérique et le développement de la personnalité dans une société numérique.

Les résultats empiriques actuels relatifs aux compétences numériques des étudiants sont alarmants, en particulier compte tenu de l'absence d'un cadre national de compétences numériques en Suisse:

- en matière de maîtrise informatique et de l'information, les étudiants suisses ne possèdent pas de compétences au-dessus de la moyenne par rapport à d'autres pays européens et près de 30% d'entre eux ne dépassent pas le niveau de compétences le plus faible;
- il a été prouvé que les étudiants suisses ont des lacunes notamment en maîtrise de l'information;
- les résultats soutiennent l'existence d'un fossé socio-économique et entre les sexes au niveau des compétences numériques;
- bien qu'ayant grandi dans le monde numérique, les étudiants ont une maîtrise insuffisante de l'Internet;
- la maîtrise objective des étudiants est beaucoup moins bonne que la maîtrise subjective qu'ils ont évaluée eux-mêmes;
- en raison d'un taux de réponse très faible, aucune analyse des compétences des professeurs tirée de l'étude ICILS 2013 n'est disponible publiquement en Suisse.

La professeure Seufert conclut son rapport par les six points suivants: 1. sensibiliser davantage aux compétences complémentaires; 2. développer un cadre national de compétences numériques; 3. établir des évaluations formatives, des systèmes d'évaluation intégrés et un système de portefeuille de fin d'études; 4. permettre d'apprendre par soi-même dans les établissements d'enseignement; 5. renforcer les capacités en développant les compétences numériques des professeurs; 6. continuer les recherches dans le domaine des compétences numériques pour combler le fossé de la «société dans la boucle».

Competenze digitali

L'effetto principale della digitalizzazione sul modo di vivere e lavorare è rappresentato dall'aumento delle capacità umane attraverso l'uso di macchine. L'attuale dibattito non dovrebbe quindi essere incentrato sulla sostituzione della forza lavoro.

Per capire l'interazione tra uomo/società e macchine, la prof.ssa Seufert presenta una struttura proposta da Iyad Rahwan, professore associato presso il MIT, che passa da un semplice «human in the loop», dove l'uomo stabilisce obiettivi, limiti ecc. per il funzionamento delle macchine, a una «society in the loop», che integra valori etici, leggi e norme sociali nella gestione dei sistemi automatici (intelligenza artificiale ecc.).

Per implementare correttamente questi due approcci sono necessarie competenze digitali, che dovrebbero essere inserite nel sistema educativo come disciplina trasversale sulla base di un «curriculum a spirale». Tali competenze sono l'alfabetizzazione e la cittadinanza digitale nonché lo sviluppo della personalità in una società digitale.

I risultati empirici sul livello degli studenti in quest'ambito sono allarmanti, soprattutto data l'attuale mancanza di un quadro di competenze digitali in Svizzera:

- in termini di alfabetizzazione informatica, gli studenti non presentano competenze superiori alla media rispetto ad altri Paesi UE e quasi il 30% non supera il livello più basso;
- è emerso che gli studenti presentano deficit in particolare nell'alfabetizzazione informatica;
- vi è consenso sull'esistenza di un divario socio-economico e di genere nelle competenze digitali;
- sebbene gli studenti siano figli dell'era digitale, non possiedono abilità informatiche sufficienti;
- l'alfabetizzazione oggettiva degli studenti è nettamente inferiore a quella percepita;
- a causa del tasso molto ridotto di risposta, non è stata resa pubblica alcuna analisi dello studio ICILS 2013 sulle competenze dei docenti in Svizzera.

La prof.ssa Seufert conclude il suo articolo rilevando sei punti fondamentali: 1. sensibilizzazione sulle competenze complementari; 2. sviluppo di un quadro nazionale di competenze digitali; 3. istituzione di verifiche formative, sistemi di valutazione integrati e portafoglio qualifiche; 4. ammissione dell'autoapprendimento in istituzioni di formazione; 5. aumento delle capacità attraverso lo sviluppo delle competenze digitali dei docenti; 6. ulteriori ricerche nell'ambito delle competenze digitali per colmare la lacuna della «society in the loop».

Digital competences

Paper commissioned by the Swiss Science and Innovation Council SSIC

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Professor Sabine Seufert, University of St. Gallen

With an introductory comment by Professor Alexander Repenning, University of Applied Sciences and Arts Northwestern Switzerland and University of Colorado

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About the authors

Dr. Sabine Seufert holds the Chair for Business Education and is Director of the Institute of Business Education and Educational Management at the University of St. Gallen. At the Institute she leads the swiss centre for innovations in learning (scil), initiated and founded with the support of the Gebert Rüf Foundation.

Seufert studied business administration, information management, and pedagogy at the University of Erlangen-Nuremberg and received her Ph.D. in information management at the University of Muenster in 1996. In 2006 she finished her habilitation at the University of St. Gallen (venia legendi in business education and educational management).

After her academic studies she worked two years as higher education teacher at vocational schools in Bavaria and received her teaching diploma in 1997. From 1997 to 1999 she was co-founder and project manager for the Learning Center at the University of St. Gallen. From May 1999 to 2001 she was responsible for the Executive MBA in New Media and Communication under the lead of Prof. Peter Glotz at the Institute for Media and Communication Management at the University of St. Gallen. In 2000 she stayed as visiting scholar at the Stanford Learning Lab and in 2008 as visiting professor at the University of Southern Queensland, Brisbane.

Dr. Alexander Repenning is the Hasler Professor and Chair of Computer Science Education at the PH FHNW (School of Teacher Education at the University of Applied Sciences and Arts Northwestern Switzerland), and is a computer science professor at the University of Colorado. He is directing the Scalable Game Design Initiative at the University of Colorado.

Repenning's research interests include education, end-user programmable agents, and artificial intelligence. He has worked in research and development at Asea Brown Boveri, Xerox PARC, Apple Computer, and Hewlett Packard. Repenning is the creator of the AgentSheets & AgentCubes simulation and game computational thinking tools. He has offered game design workshops in the USA, Mexico, South America, Europe and Japan. His work has received numerous awards including the Gold Medal from the mayor of Paris for "most innovative application in education of the World Wide Web", as well as "best of the best innovators" by ACM and has been featured in WIRED Magazine. Repenning has been a Telluride Tech Festival honoree for contributions to computer science. He is an advisor to the National Academy of Sciences, the European Commission, the National Science Foundation, the Japanese Ministry of Education and the Organisation for Economic Co-operation and Development (OECD).

Introductory comment by Professor Alexander Repenning

In her position paper on Digital Competences, Dr. Sabine Seufert is identifying some of the key challenges posed to society by the digital revolution. She paints a somewhat alarming picture particularly with respect to employment. Just like most revolutions, even with the best of original intentions, the outcome of this revolution, due to its enormous speed, may not only be hard to predict but may have dire consequences for society. Will jobs be lost due to massive automation of mechanical chores through robots or will humans engaging in cognitive processes be replaced by artificial intelligence? Then again, the digital revolution may result in a new kind of digital prosperity transforming society for the better. To cope with this intrinsically difficult process, Dr. Seufert is suggesting a number of guiding questions and offers a vision for educational policy makers based on the notion she refers to as "digital competences 2030."

Dr. Seufert's vision to make the best of the digital revolution is the notion that she calls augmentation, by which she means a yin and yang-esque symbiotic complement of human abilities with computer affordances. Quite carefully, in her vision, she is exploring a societal sweet spot of human-machine interaction explicitly avoiding technology use cases where machines are replacing humans. Innovation in IT makes machines evolve at unnerving rates to become more versatile, faster, better, and smarter. The only means for humans to participate meaningfully in this ever changing symbiosis will be through systemic education resulting in crucial digital competences relevant to the 21st-century workforce. Digital education, that is the process of acquiring these digital competences, is the key to augmentation.

At this point, it is still less clear what these digital competences should be. Among other things, Dr. Seufert calls out the notion of computational thinking. This concept, embodying the idea of problem-solving with computers, has not only become highly popular, particularly in the USA, but has also become the core idea of numerous well-funded government initiatives advancing digital competences. Empirical studies assessing digital skills, such as the ICILS and the PISA study cited by Dr. Seufert, suggest average performance of Swiss students. However, these studies are focused mostly on application-use competence, e.g., how to use products such as Microsoft Word, or social media competence, and provide limited insight into the computational thinking skills of Swiss students. Fortunately, newer versions of theses studies, including the assessment of computational thinking, are currently under development.

A layered spiral curriculum approach is suggested as the foundational for a digital competence framework. Starting with digital literacy, already at the primary school level, students gain critical understanding of technology including some basic understanding of programming as well as the use of artificial intelligence, statistics, natural language processing and data security. Then students move on to digital citizenship as means to understand responsible use of technology to solve real world problems. Moving further still towards higher education, students gradually develop a sophisticated sense of critical thinking, including computational thinking, as well as social and self-competence to become responsible and self-determined personalities. Dr. Seufert does list a number of potential challenges accompanying this framework. Of particular concern is teacher professional development to successfully train teachers that can employ digital media for the purpose of education in their classrooms effectively. An additional concern is rooted in common teaching practices, which are not only slow in the uptake of new ideas but also often even hostile towards innovation.

Conclusions and comments

The position paper closes with six conclusions aimed at educational policy makers. Each conclusion is listed in their short form (italics) plus comments:

1. Awareness: *Leaders, educational policy makers, have to develop a vision for the successful partnership of human and machine, with the aim to win synergy through complementary competences.* A symbiotic nature of human abilities and machine affordance interactions is clearly desirable but the scope, and speed of machine evolution make the co-evolution of human-machine interaction nearly impossible to predict. Politics and education typically follow reactive and not proactive patterns. This will make the development of appropriate visions quite difficult and will require leaders and educational policy makers that are deeply connected to the scientific community.

2. Curriculum: *A national digital competence framework as a spiral curriculum with transversal educational policy status should be developed.* Developing this kind of curriculum will be essential but it will be challenging to inject a new competence framework into the existing curriculum landscape in Switzerland (e.g., Lehrplan 21). Switzerland is still in the lengthy process to adopt the current Lehrpan 21 in the 21 German speaking Kantons. However, with relative small conceptual shift, the suggested digital competence framework could be constructively aligned with the "Informatik" and "Medien" subject areas of the Lehrplan 21. The Lehrplan 21 does provide the necessary flexibility to enable this kind of adaptation.

3. Assessment: *New ways of assessment and measurement of digital competences are needed. Enhanced formative assessments (based on national assessment banks) need to be integrated into the assessment systems. In general, the grading system in education needs a dramatic change from standardized testing to graduation portfolio systems.* Progressive research in the learning science is already heading in this direction. For instance, instruments have been developed and validated to enable formative as well as summative evaluation approaches for computing computational thinking. These approaches, instead of administering traditional tests on programming skills such as multiple choice tests, allow students to simply create programming projects such as simulations and then have certain algorithms identify concepts expressed in their code to gage competences automatically.

4. DIY learning: *Do-it-yourself (DIY) learning should be encouraged in primary, secondary, and higher education institutions. A new mindset of creativity, innovation, and self-organisation (sharing culture) should be actively fostered in order to promote school and organisational development.* The theoretical value of designing/building based learning approaches has been recognized in the learning sciences for a long time. Constructivist, and constructionist learning have been advocated by researchers such as Papert as early as 1970. Most key challenges emerge from practical concerns implementing constructionist ideas in the context of innovation-resistant organizations such as schools. The benefits of constructionist learning are often difficult to gage, making it difficult to justify real, or perceived, overhead in teaching and evaluation. The Maker movement has brought back some of the constructionist spirit but has not yet developed a strong learning model anchored in the learning sciences.

5. Teacher Professional Development: *One of the key success factors are school teachers. A major initiative for the competence development of teachers is needed. The conceptualization and design of suitable education training measures for teachers require a systematic approach to the professional development of teachers.* Without any doubt, teacher professional development is one of the key enablers of digital education. In the short run, in-service teacher professional development, e.g., short summer workshops, will enable a small number of self-selected teachers to progress into this new territory. In the longer run, however, it will be necessary to integrate the training of pre-service teachers into required classes offered by schools of education. Systemic impact requires approaches exposing all teachers.

6. Research: *Digital competences at an organizational level need further investigation: Closing the "Society-in-the- loop" gap and learning analytics or academic analytics are examples of the new research field "digital competences at organizational level."* This research field is extremely important but vast and completely underdeveloped in Switzerland. The following section provides an elaboration of this point providing some suggestions on how Switzerland could transform its research potential in this field.

Opportunities and challenges for Switzerland to become a digital competences leader

Overall the position paper makes a compelling case for being more progressive with the digital competences education in Switzerland. However, an even more reforming position could be to become a digital revolution leader. That is, instead of focusing mostly on measures to catch up with the revolution one could employ the unique innovation potential of Switzerland to formulate a truly transformative approach aiming at a leadership position. The digital revolution hinges on Computer Science Education (CSE) and on Computer Science Education Research (CSER). Given its unique infrastructure and established culture of innovation (e.g., a high number of patent applications per capita), there are three opportunities that amount to a very high potential for Swiss leadership:

1. High degree of Research Funding Levels. The US National Science Foundation has a $7.4 billion (2017) budget compared to $0.98 billion (2016) of the Swiss National Science Foundation (SNSF). Adjusted for population, that suggests a per capita research budget of $21per person and per year in the USA and $117 in Switzerland. This is a five-fold advantage for Switzerland to fund basic research. To make matters worse for the USA, President Trump has proposed an 11% US National Science Foundation (NSF) budget cut for 2018.

2. National Computer Science Curriculum. The Lehrplan 21 is a national level (elementary and secondary school) curriculum serving the 21 German speaking Kantons of Switzerland. Adoption is not 100% but is growing at a steady pace. The Lehrplan 21 does include Computer Science and Media competences that are highly relevant to a digital competency framework.

3. Systemic Pre-Service Teaching Capacity Creation. Swiss Schools of Education are starting to offer required computer science courses to pre-service teachers. For instance, the PH FHNW, starting in Fall of 2017, will require all of its 800 pre-service elementary school teachers to become fluent in Computational Thinking. A dense network of schools of education could result in an unprecedented, systemic level of Swiss-wide teacher professional development in Computer Science.

The current thought and implementation leaders of computer science education – the USA and the UK – cannot quite match Switzerland's opportunity profile. They do not have the required combination of funds, national curriculum, and professional development capacity. Unfortunately, for Switzerland to reach this potential it will have to overcome two main obstacles:

1. CSER is not well aligned with Switzerland's Research Funding model. For instance, the human/machine interaction angle, common to most computer science education research, does not fit well with the SNSF model division categorization. CSE is not recognized as an area of concern and is perceived as vocational service, and not as a research challenge.

2. CSER Output in Switzerland is practically nonexistent. The causal connection between research funding and research output is hard to disentangle but the number of publications in the field of CSER in Switzerland is extremely low even when adjusting for the size of its population. Universities, including the ETH Zurich and EPF Lausanne as well as schools of education, woefully underperform in CSER compared to other nations, especially the USA and the UK.

Strategy

Computer science education research needs to be recognized as the basis for the digital revolution that needs to be supported by the SNSF. The leadership position of the USA in the digital revolution can, in large parts, be traced back to the support of CSER by the NSF. For many decades NSF has pioneered CSER through a number of dedicated CSER funding programs. These programs have contributed to basic research by advancing learning sciences but also by supporting practical concerns such as broadening participation in computer science through innovative technology experiences for students and teachers. Switzerland is wavering with respect to its investment into the digital revolution. Ideally, government funds considered for digital revolution should be channeled through the Swiss National Science Foundation as CSER focused research solicitations such as National Research Programs.

1.1
Introduction

1.1.1
Goal of the paper

Digital transformation is currently the topic with regard to our living and working environment. Digitalisation not only changes the way we live and work, but also how we interact with others. It will further introduce new ways of consuming and producing goods and services. We certainly are in a situation of radical change. However, what awaits us in the future is not clear. At the same time, all industries will be affected by the digital disruption, particularly health care, public administration, and education (Becker, 2015; Becker, 2016; World Economic Forum, January 2016).

Digital competences of leaders, employees, and citizens are key factors to successfully cope with this uncertain future (Becker & Knop, 2015; Johnson et al., 2016; Kienbaum Consultants International GmbH & Bundesverband Digitale Wirtschaft e.V., 2016; Studiengemeinschaft Darmstadt, 2016; Wachtler et al., 2016). But what exactly are digital competences? How can digital competences be operationalised and developed?

This paper thus focuses on digital competences. It will look at the status quo and identify relevant future directions. It is the aim of this paper to provide a solid orientation for educational policy makers, including the introduction of a digital competence framework. However, my paper cannot cover all aspects relevant to this complex topic. My intention is rather to identify the right questions to ask and to provide some orientation on how to move on to further investigate digital competences in a medium- to long-term perspective, and also to reveal possible "blind spots". The aim is to survey the multiple dimensions of this complex subject in order to outline a fundamental approach for tapping the potential of "digital competences for 2030".

1.1.2
Problem statement: New human-machine interaction

In terms of long-term future scenarios, two contrasting positions are argued for: There is either the danger of a digital revolution costing a lot of jobs; or one expects an evolutionary development with new jobs and a higher prosperity for society. Which scenario will prevail depends on decision makers in politics and the economy today, as Brynjolfsson and McAfee (2004) state.

Future university graduates are the decision makers of tomorrow. As change agents, they can act responsibly with regard to a digitalisation of the working environment and actively shape it, or they are driven as functionary elite by the developments. Management as a reflective discipline has to make decisions that are aligned with norms and moral concepts. The current situation of change offers the opportunity to ask fundamental questions: In what kind of a society do we want to live? What does the economy contribute? What kind of idea of mankind do we impose, when designing the future interaction of humans and machines? In this context, universities are challenged to prepare future leaders as decision makers.

Before I continue, it is important to first elaborate on what digitalisation stands for. According to Seufert and Vey (2016) digitalisation in its most comprehensive form comprises:

- The expansion of the Internet through a connection of things (Internet of Things);
- Processes and control systems that work mostly digitally;
- Big Data and elaborate predictive and prescriptive analytics;
- The growing use of artificial intelligence (AI) and digital assistants as a decision support;
- The discovery of hidden connections in the enormous data volume of the digital universe.

Due to digitalisation, significant changes in functions and behaviour on individual, organisational, and social levels can be detected.

In the public debate, substitution (i.e. the replacement of jobs) is the primary focus as the lead story of Der Spiegel in September 2016 shows: “Wie uns Computer und Roboter die Arbeit wegnehmen und welche Berufe morgen noch sicher sind”[36] (Der Spiegel, 2016). Marc Andreessen penned his famous “Why software is eating the world” essay in The Wall Street Journal five years ago. “Digital Disruption” emerged as a new term in recent years and has seen almost excessive use: No matter your industry, managers reimagine their business to avoid being the next local taxi company or hotel chain caught completely off guard by their equivalent of Uber or Airbnb. With the upcoming technologies (AI and robotics) knowledge work will dramatically change. One could rephrase Andreessen’s quote: “Software is eating management.”

While optimists talk about an economic miracle, opponents of digitalisation forecast the end of work. However, there is a danger that society focuses too much on short- and middle-term demands that emerge from economic pressures, and neglect long-term implications of the current technological developments.[37] The new challenge of human augmentation is more subtle and difficult to grasp. Although books such as Frank Pasquale’s “The Black Box Society” and Eli Pariser’s “The Filter Bubble” have gained a lot of attention, the issue seems to be neglected in the educational debate. Furthermore, although these writings help illuminate many of the challenges, they often fall short of supplying viable solutions. This paper intends to shed light on this “blind spot” and argues that human augmentation is the major challenge of the fourth industrial revolution.

1.1.3

Augmentation is the key challenge for society and education

Definition, forms of augmentation

Imagine the following situation:

You feel really bad physically and decide to visit the emergency service at a local hospital. When it is your turn, two physicians enter, an elderly physician on duty together with his youngish assistant. The elderly physician says he commands 30 years of experience, he will find out what is wrong with you. The youngish assistant says he works with a computer database which comprises the knowledge of 600 years of western medical practice.

Who would you rather turn to?

I admit that the example is not very realistic as in practice the elderly physician will also have the best computer equipment. So we as patients will not have to decide between the two options. However, the imagined situation demonstrates the developments in medical diagnoses and why we should come to terms with the changes in human-machine interaction.

In the healthcare system one person will generate 1 million gigabyte of health-related data during her or his lifetime – equivalent to about 300 million books (according to Karin Vey, IBM Research ThinkTank). One example of augmentation is interactive machine learning for health informatics. When do we need the human-in-the-loop (HITL)? Holzinger (2016) recently explored this question in his research paper. The following section is a quote from his research (abstract) and demonstrates how humans and machines interact with complementary competences:

> Machine learning (ML) is the fastest growing field in computer science, and health informatics is among the greatest challenges. The goal of ML is to develop algorithms which can learn and improve over time and can be used for predictions. Most ML researchers concentrate on automatic machine learning (aML), where great advances have been made, for example, in speech recognition, recommender systems, or autonomous vehicles. Automatic approaches greatly benefit from big data with many training sets. However, in the health domain, sometimes we are confronted with a small number of data sets or rare events,

36 English translation: “How computers and robots take away our work and which jobs will still be safe tomorrow.”

37 This is sometimes referred to as Amara’s law: “We tend to overestimate the effect of a technology in the short run and underestimate the effect in the long run.”

where aML-approaches suffer of insufficient training samples. Here interactive machine learning (iML) may be of help, having its roots in reinforcement learning, preference learning, and active learning. The term iML is not yet well used, so we define it as "algorithms that can interact with agents and can optimize their learning behavior through these interactions, where the agents can also be human." This "human-in-the-loop" can be beneficial in solving computationally hard problems, e.g., subspace clustering, protein folding, or k-anonymization of health data, where human expertise can help to reduce an exponential search space through heuristic selection of samples. Therefore, what would otherwise be an NP-hard problem, reduces greatly in complexity through the input and the assistance of a human agent involved in the learning phase. (Holzinger, 2016, p. 119)

Decisions on all management levels increasingly have to be made in consideration of computer-based data analyses and one's own gut feeling. Decision makers have to learn in what cases algorithms can help them to detect distortions in their thinking and when intuition in form of condensed knowledge comes into play. It is about being able to design flexible decision processes, understanding the role of digital tools, and using them competently. A cognitive assistant equipped with AI can make statistically sound proposals on the basis of enormous data volumes. Nonetheless, these results are limited. The proposals refer only to a specific area which we specify for the machine and questions that we have trained with the system. In contrast, humans are able to make holistic evaluations of a situation. A decision maker has to know about the different competences and limitations of machines on the one hand, and humans on the other hand, and to be able to design adequate decision processes (cf. Figure 3.1).

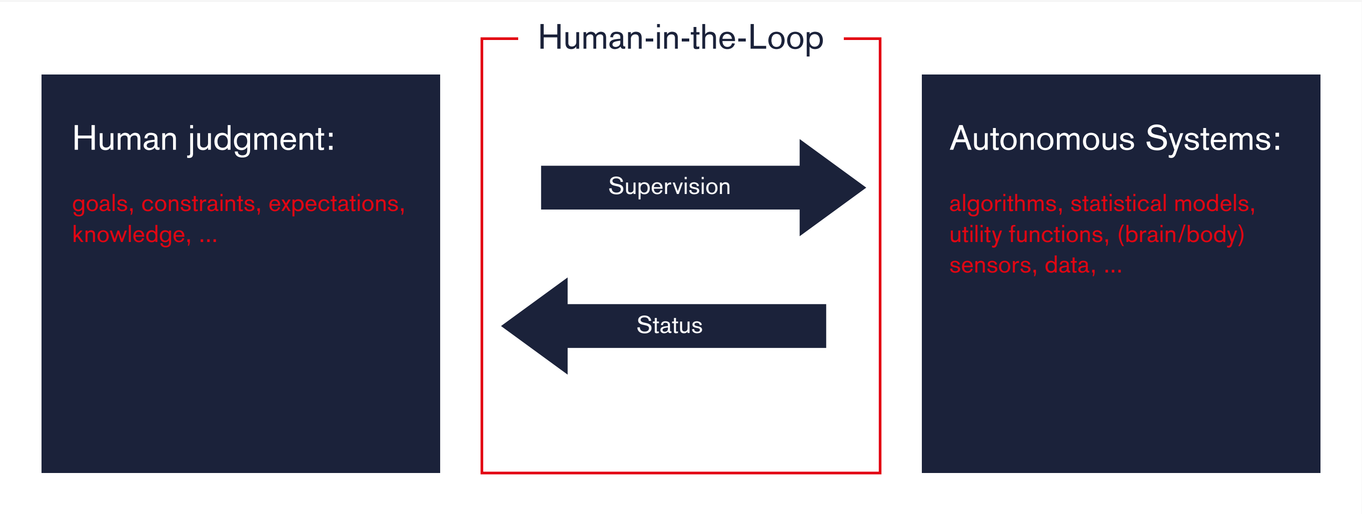


Figure 3.1. Human-in-the-loop (Rahwan, 2016)

Future forms of augmentation can already be observed today and investigated more deeply to elaborate future scenarios. As the American science fiction author William Gibson stated: "The future is already here — it's just not very evenly distributed." Table 3.1 below gives an overview of different forms and examples of human augmentation.

Form of Augmentation	Examples
Physical Augmentation: Advanced robotic devices that adapt to their environment or as integral parts of the human body ("Human 2.0")	– A paralysed man has made the first kick of the FIFA World Cup 2014 using a mind-controlled robotic exoskeleton. – Advanced robotic devices that are sufficiently small, safe and flexible to be inserted into human workflows, e.g. robotic surgery combines the advantages of small incisions with computer-assisted precision, enhanced vision and improved dexterity.
Cognitive Augmentation: Technologies that "learn" by observation and offload routine knowledge work to automated assistants	– Intelligent Personal Assistants: Cognitive assistants for all occupations are beginning to appear (IBM Watson, Apple Siri, Microsoft Cortana, Google Now, Amazon Echo, etc.) – Chess grand masters are getting younger and younger (Sergey Karjakin is only 12 years old). Why? They do not play against the computer, they play with the computer (to develop complementary competences).
Collaborative Augmentation: Software directly improves the ways humans coordinate work and co-create new products, learning together with the computer	– Learning-to-learn Competences: designing learning scenarios for self-regulated learning by using digital media – Providing instructional material, learning techniques
Emotional Augmentation: New human-machine interaction with social robots (which interact and communicate with humans by following social behaviours and rules attached to their role)	– In education & research: The social robot "NAO" serves as avatar for ill children in the classroom, therapy intervention with autistic children; NAO as a teaching assistant for refugee children learning German. – In business: Human robot "Pepper" for the retail industry, customer service, e.g. Nescafé Japan uses Pepper to sell coffee. – As training partners: "Showa Hanako 2" Dental Surgery Robot reacts like a human during dental treatment for training novices. – As team member: Chatbot "Nadia" as an employee of an Australian bank (voiced by Cate Blanchett). – As boss: Robots are allowed to communicate to someone that he or she is fired, it only needs a human being for the signature.

Table 3.1. Forms of augmentation: Examples for new human-machine interaction

With the digitalisation of knowledge work, augmentation is the real new challenge we have to face, and not substitution through automatisation (Autor, 2015). It is of considerable importance not to see work as a zero-sum game where machines gain an ever-increasing part (McAfee & Brynjolfsson, 2015). Many things that today cost a lot of time for a knowledge worker, like time-consuming research, can be done by computer systems in the future. Only in cooperation with the machine considerable improvement of quality is possible – collected knowledge will be newly, better and considerably more economically usable. This allows a considerably wider support of decisions. However, without the human to give the direction, machines provide only fragmented or irrelevant results.

"Human-in-the-loop (HITL)" and "Society-in-the-loop (SITL)"

With the development of algorithms and AI systems, HITL acquires a broader meaning in a new training field: the role of humans in the training of the machine. Today, many apps already learn from human behaviour in order to improve their ability to take over routine work (e.g. SMS systems, cognitive automation). Further fields of AI are for instance media diagnosis or robotic warfare. Such systems are more complex to develop. One of the main problems is that AI engineers are training the systems using huge amounts of data (Big Data) but usually are not domain experts. Therefore, any biases or errors in the data will create models reflecting those biases and errors. That is the reason why Ito (2016) demands a human lens for AI:

> Human-in-the-loop machine learning is work that is trying to create systems to either allow domain experts to do the training or at least be involved in the training by creating machines that learn through interactions with experts. At the heart of human-in-the-loop computation is the idea of building models not just from data, but also from the human perspective of the data. (Ito, 2016, para. 4)

Recently, Rahwan (2016), Professor at MIT Media Lab emphasised the need for a scaled-up version of HITL in his blog: a "Society-in-the-loop" approach for developing AI systems with wide societal implications. He asks what happens when

> an AI system does not serve a narrow, well-defined function, but a broad function with wide societal implications? Consider an AI algorithm that controls billions a [sic] self-driving cars; or a set of news filtering algorithms that influence the political beliefs and preferences of billions of citizens; or algorithms that mediate the allocation of resources and labor in an entire economy. (Rahwan, 2016, para. 5)

This is the reason why he demands a

> qualitative shift from HITL to society in the loop (SITL). … SITL is about embedding the judgment of society, as a whole, in the algorithmic governance of societal outcomes. In other words, SITL is more akin to the interaction between a government and a governed citizenry. … Similarly, SITL can be conceived as an attempt to embed the general will into an algorithmic social contract. (Rahwan, 2016, paras. 5–6)

Furthermore, Rahwan (2016) argues that we face a SITL gap, because

> we still lack mechanisms for articulating societal expectations (e.g. ethics, norms, legal principles) in ways that machines can understand. We also lack a comprehensive set of mechanisms for scrutinizing the behavior of governing algorithms against precise expectations. … Putting the society in the loop requires us to bridge the gap between the humanities and computing. (Rahwan, para. 14)

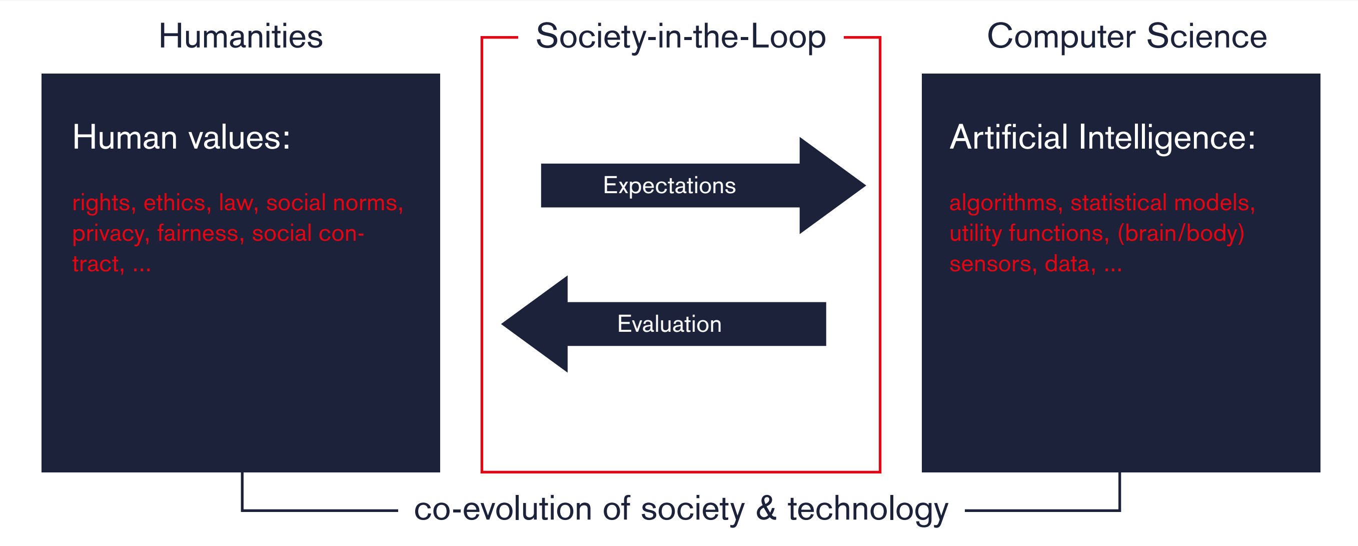


Figure 3.2. Society-in-the-loop (Rahwan, 2016)

Looking at Rahwan's (2016) model of SITL (as depicted in Figure 3.2), one might get the impression that in the current debate computer science gets all the attention. However, the co-evolution of society and technology is key. Both human values and AI are constantly co-evolving as Rahwan (2016, para. 15) illustrates: "Thus, the evolution of technical capability can irreversibly alter what society considers acceptable – think of how privacy norms have changed because of the utility provided by smart phones and the Internet." A main success factor will (therefore) be to develop adequate digital competences of a society.

Main thesis:
Leaders, educational policy makers, must understand the connection of human and computer and develop a vision for the successful partnership of human and machine – human values and AI –, with the aim to gain synergy through complementary competences.

1.2 Digital competences

1.2.1 Definition

The European Commission provides the following definition: Digital competence involves the confident and critical use of Information Society Technology (IST) for work, leisure and communication. It is underpinned by basic skills in ICT: the use of computers to retrieve, assess, store, produce, present and exchange information, and to communicate and participate in collaborative networks via the Internet. (European Commission, 2007, p. 7)

The EU framework of digital competences identifies the respective key components in five areas: information, communication, content creation, safety, and problem solving. To be competent, one needs instrumental skills, advanced skills and knowledge, and appropriate attitudes in applying these skills and knowledge – as shown in Figure 3.3 below.

This EU framework serves as a normative orientation in most European countries. Many EU countries have planned or already decided on a new national digital competence framework. There is no doubt that digital competences have become a core competence in the 21st century. There are similar developments in other countries outside the EU.

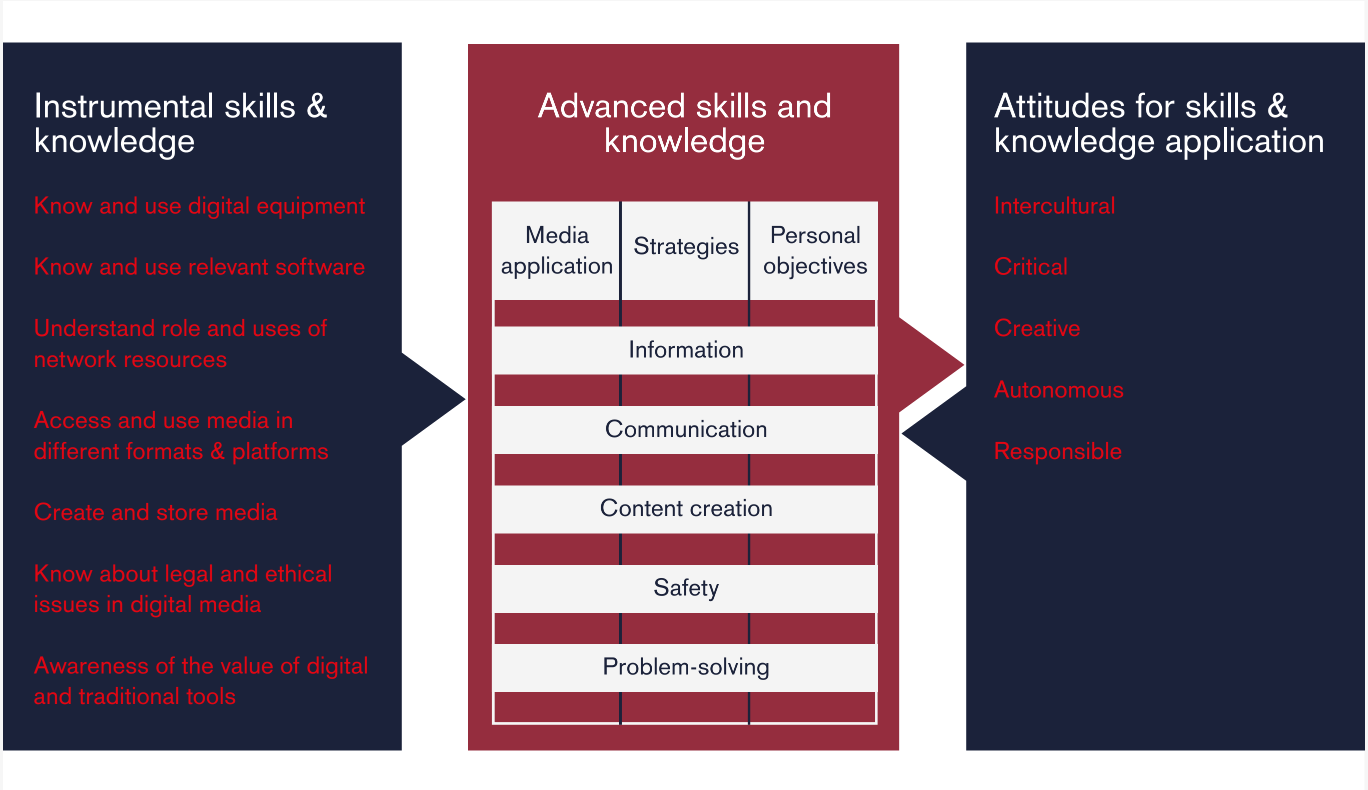


Figure 3.3. EU framework of digital competences, own representation based on Ferrari (2013) and Ala-Mutka (2011)

The World Economic Forum[38] defines the term "digital competences" as a "set of social, emotional and cognitive abilities that enable individuals to face the challenges and adapt to the demands of digital life." The DQ Institute[39] defines it as "having the necessary knowledge, skills and ability to adapt one's emotions and adjust one's behaviour to deal with the challenges and demands of the digital era." As part of it, the DQ Institute has identified eight aspects of digital citizenship and concludes that "these aspects are often overlooked as most people tend to focus on creativity and entrepreneurship".

1.2.2
Concepts of digital competences

Digital competence should play an essential part in a comprehensive education framework. Without a national digital education programme, command of and access to technology will be distributed unevenly and create new inequality – a digital divide on a new level. In most countries, digital competence is given transversal status in educational policy: Existing studies indicate that many national curricula have moved towards integrating transversal competences as a response to the number of social, economic, and cultural changes brought on by the rapid development of information and communications technology (ICT) (Voogt & Pelgrum, 2005).

Therefore, the main challenge seems not to be whether a national curriculum is needed, it is rather the question of how and to what extent transversal competences should be expressed in national and school curricula. Different education systems utilise different methods of integrating the teaching and learning of transversal competences into the curriculum. In general, there are three possible modes, which can be combined with each other:

- New specific subject: A subject with specific goals, new content and syllabi for formal teaching.
- Cross subject: Learning of transversal competences runs across, infiltrates and/or underpins all "vertical subjects", i.e. traditional school subjects.
- Extra-curricular: Learning of transversal competences is made part of school life and embedded purposefully in all types of non-classroom activities.

Many countries enrich their system and pursue a multiple mode (according to the study of Ananiadou & Claro, 2009, ICT-related content was predominantly added as new and separate subjects). Studies tend to support the incorporation of transversal competences across the curriculum due to the domain's complex and cross-disciplinary nature (Voogt & Roblin, 2012). Multiple countries have introduced policies and curricula aimed at cultivating transversal competences. Furthermore, in many countries a so called "spiral curriculum" from kindergarten to sec II (K-12) for integrating digital competences as transversal competences has been developed.

The main problem in coping with the dynamics of digital competences lies in the fast and ever evolving nature of the digital world, where proper educational government for developing digital competences is slow to catch up. Currently, Wales, for instance, explores a new approach with its digital competence framework: An interactive website informs about the framework, gives examples for learning tasks, and offers feedback mechanisms for the public (providing a dialogue-oriented platform).[40]

Generally, little attention is paid to which aspects are really new and why transversal competences are beneficial to students. This is problematic since many of the competences defined as transversal are not necessarily new nor completely absent in the existing curricula (e.g. problem solving, critical thinking, and collaboration). There is a strong need to better connect digital competence with these existing transversal competences. What is really new is to put these "old" transversal competences to a higher level in interaction with the machine (iML).

New concepts such as computational thinking as a problem-solving process have become popular, sometimes already titled the fourth cultural technique. According to Wing (2006, p. 33), computational thinking "represents a universally applicable attitude and skill set everyone, not just computer scientists, would be eager to learn and use."

38 https://www.weforum.org/agenda/2016/06/8-digital-skills-we-must-teach-our-children/

39 https://www.dqinstitute.org/what-is-dq/

40 http://learning.gov.wales/resources/browse-all/digital-competence-framework/?lang=en

1.2.3
Empirical studies

What do we know from empirical evidence, what is the status quo – how "digitally competent" are our students when they enter higher education? The following four studies and indices provide an insight about digital competences in Switzerland, across Europe, as well as the United States.

International Computer and Information Literacy Study (ICILS)

The ICILS is an important new contribution to our knowledge about digital competences of students and the integration of technology in teaching and learning. The study has been carried out by the International Association for the Evaluation of Educational Achievement (IEA), and supported by the European Commission's Directorate General for Education and Culture. ICILS is the first ever internationally comparable study assessing students' computer and information literacy (IL). 60,000 eight-graders in more than 3,300 schools from 21 education systems, including nine EU countries, were surveyed and assessed. As a result, ICILS 2013 as an educational monitoring study expands the perspective of previous international comparative educational assessment studies such as TIMSS (Trends in International Mathematics and Science Study), PISA (Programme for International Student Assessment), and IGLU (Internationale Grundschul-Lese-Untersuchung).

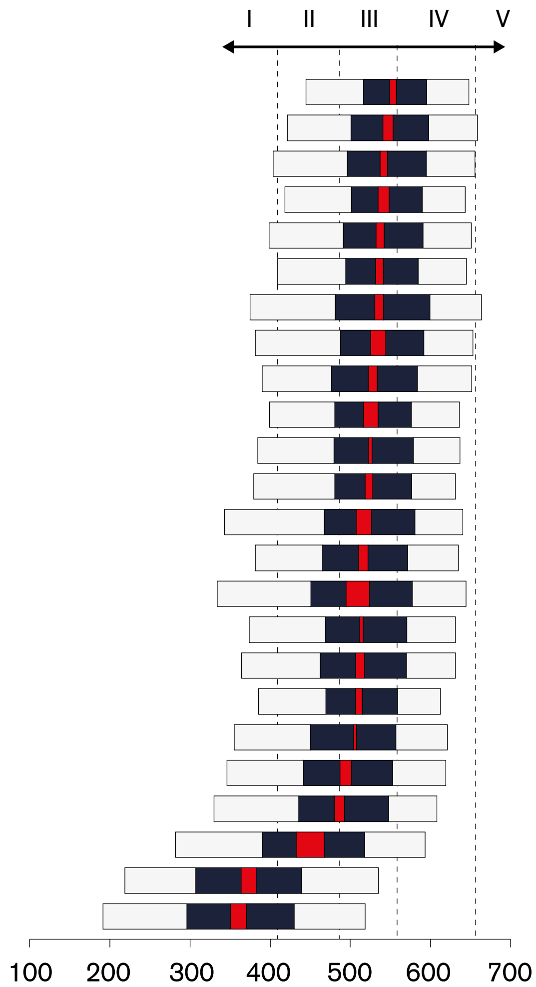
Figure 3.4 shows the results of the ICILS with the mean value (M) and the standard deviation (SD) of the reached points (maximum of 700 points) for each country. Swiss students did not score significantly above EU average. While only 2% of Swiss students reached the highest level of competence (V), almost 30% did not exceed the lowest competence level (I). Unfortunately, a detailed Swiss report is currently not publicly available,[41] however, data about Switzerland is included in the reports by Bos et al. (2014) and Eickelmann and Drossel (2016). Bos et al. (2014) conclude that the assumption under which students automatically become digitally competent by simply growing up in a world dominated by digital technologies is wrong. Students from countries with a national digital competence framework in education seem to score higher on average.

According to the ICILS website,[42] the next study will be carried out in 2018. This study will also report on the computational thinking domain, which is "understood as the process of working out exactly how computers can help us solve problems. This domain includes not only programming but also structuring and manipulating data sets." Switzerland is currently not listed as a participating country, although such a participation would be highly desirable in order to obtain and have access to relevant educational data.

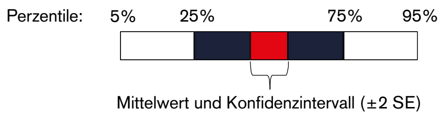
41 The initial report has been withdrawn due to a low participation ratio, although over 3,000 Swiss students participated.

42 http://www.iea.nl/icils

	Teilnehmer	M	(SE)	SD	(SE)	
	Tschechische Republik	553	(2.1)	62	(1.6)	▲
	Kanada (O.)	*547*	*(3.2)*	*73*	*(2.2)*	▲
	Australien	542	(2.3)	78	(1.6)	▲
[3]	Dänemark	542	(3.5)	69	(2.0)	▲
	Polen	537	(2.4)	77	(1.7)	▲
[1, 2]	Norwegen	537	(2.4)	72	(1.6)	▲
	Republik Korea	536	(2.7)	89	(1.5)	▲
[3]	Niederlande	535	(4.7)	82	(2.9)	▲
[2]	*Kanada (N. & L.)*	*528*	*(2.8)*	*80*	*(2.3)*	■
[3]	**Schweiz**	**526**	**(4.6)**	**72**	**(2.6)**	■
	VG EU	525	(1.1)	77	(0.7)	■
	Deutschland	523	(2.4)	78	(2.0)	■
	Slowakische Republik	517	(4.6)	90	(3.3)	■
[2, 5]	Russische Föderation	516	(2.8)	77	(1.7)	■
[2, 3]	Hongkong	509	(7.4)	95	(4.8)	■
	VG OECD	516	(0.9)	79	(0.6)	▼
	Kroatien	512	(2.9)	82	(1.7)	▼
	Slowenien	511	(2.2)	69	(1.2)	▼
	Internat. Mittelwert	**500**	**(0.9)**	**81**	**(0.6)**	▼
	Litauen	494	(3.6)	84	(2.6)	▼
	Chile	487	(3.1)	86	(2.5)	▼
[3]	*Argentinien (B. A.)*	*450*	*(8.6)*	*94*	*(4.0)*	▼
[5]	Thailand	373	(4.7)	96	(2.6)	▼
	Türkei	361	(5.0)	100	(3.0)	▼



▲ Teilnehmer, die signifikant über dem Mittelwert von Deutschland liegen ($p < .05$).
■ Kein signifikanter Unterschied zum Mittelwert von Deutschland.
▼ Teilnehmer, die signifikant unter dem Mittelwert von Deutschland liegen ($p < .05$).



Kursiv gesetzt sind die Benchmark-Teilnehmer.
[1] Die nationale Zielpopulation entspricht nicht der 8. Jahrgangsstufe.
[2] Die Gesamtausschlussquote liegt über 5%.
[3] Die Schüler- und Schulgesamtteilnahmequote liegt unter 75%.
[5] Abweichender Erhebungszeitraum.

Figure 3.4. Results of the ICILS 2013 (Bos et al., 2014). 500 points represent the international mean, I–V refers to level of competence (see Bos et al., 2014, for an explanation of competence levels)

Study “Information and social media competence” (University of St. Gallen)

Our own study “Information and social media competence” on the Lake Constance region (Seufert, Stanoevska, Lischeid & Ott, 2017) provides similar first results (434 students: 108 from Germany, 94 from Austria, 198 from Switzerland and 34 from Liechtenstein). A full-scale study with 2,000 students is planned and the results will be available at the end of 2017.

Measuring objective IL and self-assessed IL of digital natives in secondary school unveiled the discrepancy that most of the students evaluate themselves as competent, while the objective literacy is considerably lower – these results are alarming. The outcome of the study at hand is in line with the empirical evidence provided by other researchers concerning IL of digital natives: Although pupils are active users of the Internet, prior research has observed that pupils often do not have sufficient Internet skills. Most of them lack adequate web searching skills, as well as the ability to process and critically evaluate web information.

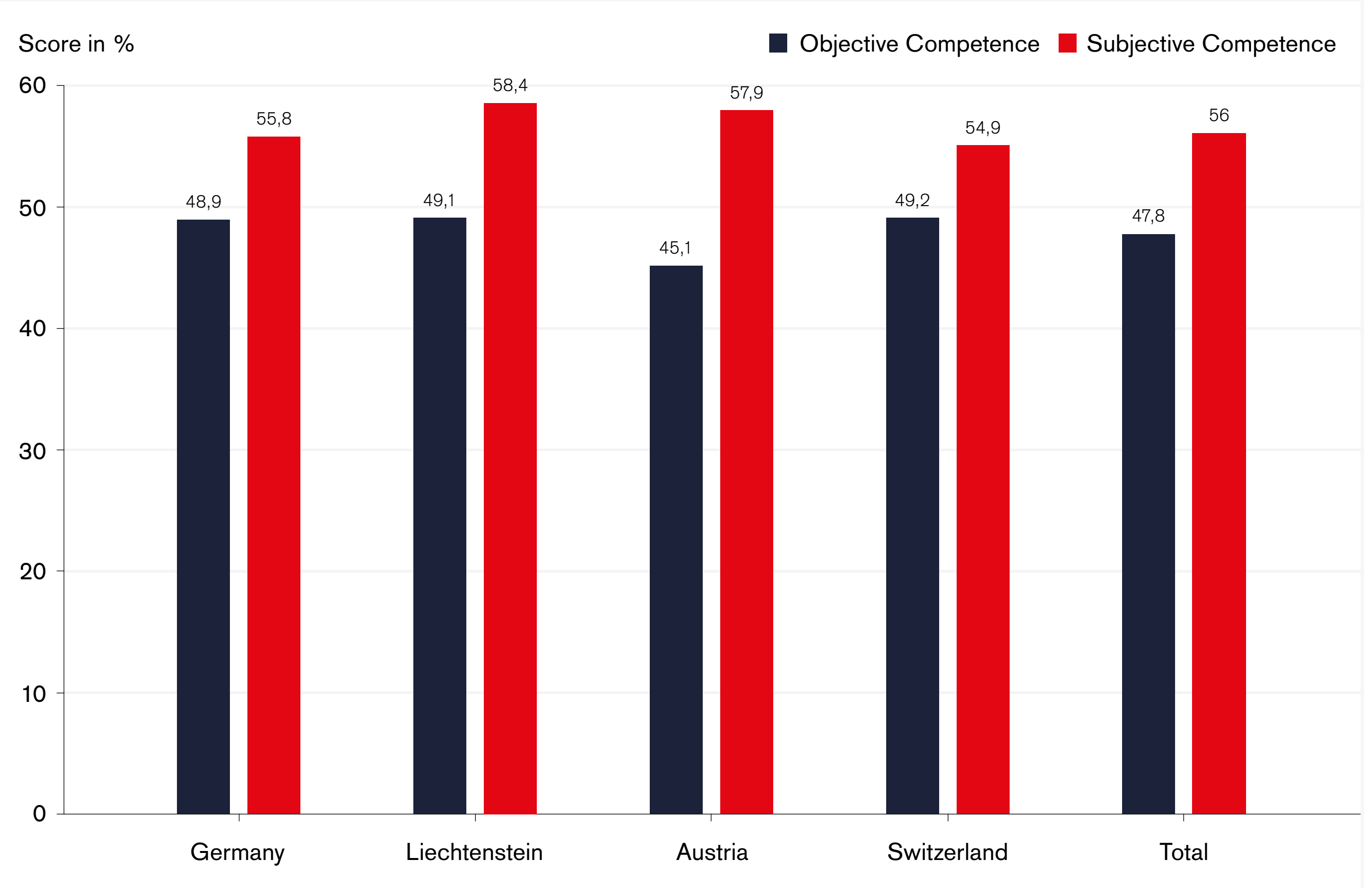


Figure 3.5. Information and social media competences at sec-II level (Seufert et al., 2017)

Study “Evaluating Information: The Cornerstone of Civic Online Reasoning” (Stanford University)

The Stanford History Education Group (2016) has analysed the civic online reasoning – “the ability to judge the credibility of information that floods young people’s smartphones, tablets, and computers.” The study administered 56 tasks to students across 12 states and collected responses from 7,804 students from middle school, high school, and college. The researchers described the information competence of the students with just one word – “bleak”. The authors published the results before the election of Donald Trump. In their conclusion they state: “we worry that democracy is threatened by the ease at which disinformation about civic issues is allowed to spread and flourish” (Stanford History Education Group, 2016, p. 5).

Digital Economy and Society Index (DESI)

The European Commission recently published the results of the 2017 DESI, a tool presenting the performance of the 28 member states in a wide range of areas: five dimensions of the digital economy and society, including human capital and digital skills in a country. The tool is a digital scoreboard providing a wide variety of visualisations of the data and with API access.

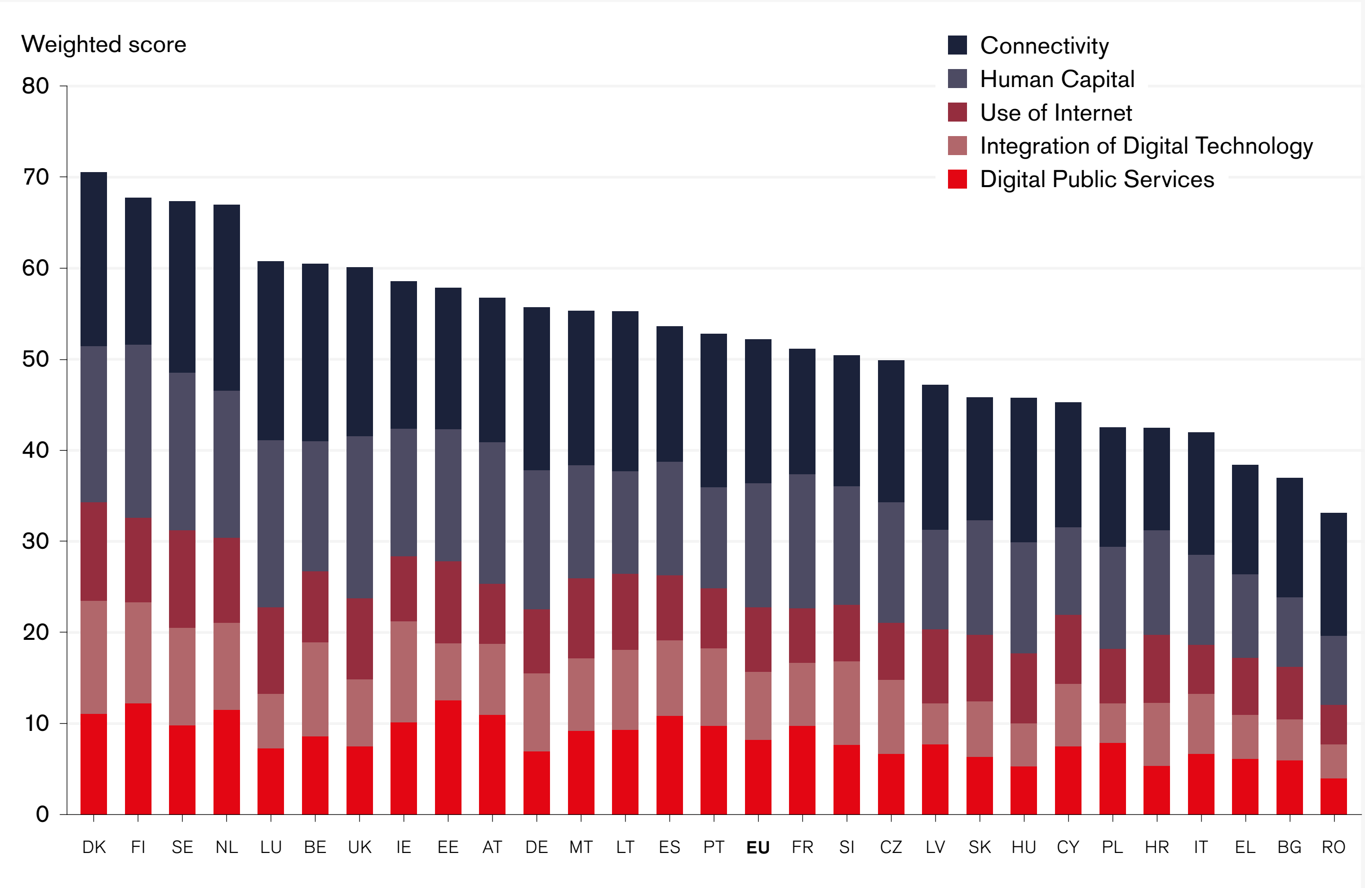


Figure 3.6. EU Digital Economy and Society Index 2017

Summary of the empirical findings

- Unravelling the digital native myth: Many “digital natives” are not digitally competent. Being born in a digital era is not a sufficient precondition for being able to use technologies in a critical, creative and informative way.

- There is a need to address gender gaps and assure a comprehensive approach to the development of digital competences in school. Additionally, it is necessary to examine how boys can be encouraged to develop the less technical aspects of digital competence to the same level as that of girls. However, girls need more support for their self-esteem, there is some empirical evidence that they underrate themselves (important for science, technology, engineering, and mathematics [STEM] subjects).

- For both genders, it is also important that the education system has a comprehensive approach to digital competences, stimulating the critical and communicative use of ICT as well as attracting young people to ICT-related careers.

- Information literacy (the fundament for “Civic Online Reasoning”) is one of the most important digital literacies. It is alarming that “digital natives” have deficits particularly in this competence area. Never have we had so much information at our fingertips. Whether this will make us smarter and better informed or more ignorant and narrow-minded will depend on our awareness of this problem and our educational response to it.

- In terms of computer and information literacy, Swiss students do not exhibit above average competences in comparison to other EU countries. Furthermore, there seems to be some evidence that Swiss students have deficits particularly in information literacy. An appropriate evaluation of information, however, is central to civic online reasoning.

1.2.4
Outlook

Currently, we are facing the implications of the “Googleisierung” (Stark, Dörr & Aufenanger, 2014) in our society. As Lobo (2013, para. 21) states, the Internet is “eben kein Bildungsautomat, sondern, ohne ein epistemologisches Fundament des Nutzers, eine Halbwissenmaschine.” The education system in its current state already exhibits numerous areas with an urgent need for action. But the digital revolution, including the economic impact of digital transformation, as well as the rapid developments in AI and cognitive computing systems put on additional time pressure. If the key challenge of augmentation remains a “blind spot”, there is a certain danger that one to two generations might get lost and a digital divide will introduce additional societal challenges.

In order to successfully tackle the key challenge of augmentation and evade the establishment of a (new) digital divide, it is necessary to introduce a comprehensive and holistic framework which establishes digital competences in the national curricula. I will present such a framework in the subsequent Section 3.3.

1.3
A digital competence framework

1.3.1
Overview of the conceptual framework

A national digital competence framework for Switzerland does not yet exist. To some extent the "Lehrplan 21" harmonises the curriculum and integrates media education. It appears that the integration mode 1 – the introduction of a new specific subject – is being applied in the educational domain:

- Primary/Sec I: "Media and informatics" (Lehrplan 21) and
- Sec II: "Informatics" in middle schools[43]/Sec II is in discussion.

Digital competence does not appear and is not given transversal status in educational policy. Only the use of digital tools in other subjects is discussed and explored. However, the connection to main transversal competencies such as problem solving is not considered (as stated before, this is a common problem, not just in Switzerland). The proposed framework as shown in Figure 3.7 tries to give an orientation of the multifaceted dimensions of digital competences and will be explained in the following subsections.

Figure 3.7. Digital competence framework

43 https://www.nzz.ch/schweiz/anhoerung-zu-mittelschul-lehrplaenen-informatik-wird-pflichtfach-ld.1296091?mktcid=nled&mktcval=107_2017-5-23

Normative orientation and values

As stated in Section 3.11: The current situation of change offers the opportunity to ask fundamental questions: In what kind of a society do we want to live? What does the economy contribute? What kind of idea of human do we have to, for example, design the future interaction of human and machine?

The debate surrounding what actually constitutes quality education and learning in the 21st century is ongoing. There is a growing concern that education systems are focusing too much on the accumulation of academic "cognitive" skills at the expense of the more elusive and hard-to-measure "non-academic" skills and competences. Beyond knowledge, these abilities must be rooted in human values of integrity, respect, empathy, and prudence. These values enable the wise and responsible use of technology – an attribute which will mark the leaders of tomorrow.

Following Aristotle, technology goes beyond the material solution to include also the rationality that lends plausibility criteria to a particular technical method and determines the appropriateness of the chosen technical means with regard to the desired purposes. "Practical wisdom" as an old intellectual virtue of practical reasoning, is becoming modern again in a digital world – as a complement to machines (Schwartz & Sharpe, 2011). Practical wisdom requires a degree of self-awareness and self-reflection:

> Practical wisdom demands more than the skill to be perceptive about others. It also demands the capacity to perceive oneself – to assess what our own motives are, to admit our failures, to figure out what has worked or not and why. … Being able to criticize our own certainties is often a painful struggle, demanding some courage as we try to stand back and impartially judge ourselves and our own responsibility. (Schwartz & Sharpe 2011, p. 18)

A digital competence framework should include the discussion about practical wisdom and an appropriate value system necessary to incorporate the "Society-in-the-loop" concept (see Subsection 3.1.3). In a digital society, the overriding goal is personality development; digital literacy and citizenship are its relevant foundations.

Digital literacies: Basic understanding and use of technology

To be digitally literate needs a basic understanding of upcoming technologies. New content has to be integrated in school curricula. Examples for discovering new human-machine interaction could be:

- Basic understanding of programming;
- Basic understanding of the various approaches to AI;
- Basic understanding and knowledge of statistics;
- Basic understanding of natural language processing;
- Basic understanding of the psychology of perception and of user guidance;
- Basic understanding of encryption and data security.

Digital citizenship: Socioeconomic impact of technology

According to the digitalcitizenship.net, "Digital Citizenship is a concept which helps teachers, technology leaders and parents to understand what students/children/technology users should know to use technology appropriately. Digital Citizenship is more than just a teaching tool; it is a way to prepare students/technology users for a society full of technology. Digital citizenship is the norms of appropriate, responsible technology use."[44] The normative orientation for the responsible use of technologies faces the main problem of the "time lag" and "parallel universes" of teachers, parents and students. Today, with the technological advances, the worries are even greater. Ribble and Bailey (2005) already raised this issue:

> Sociologists have determined with every new technology there has been a lag between the time it is introduced and the point where it becomes mainstreamed into society (Krotz, 2003). During that time, society creates rules, policies, and procedures that will help users to understand the technology. The recent wave of digital technologies has left our society gasping for air. When we begin to understand one technology, another new one comes along. In the past, it has been the adults who have taken hold of the technology, come to grips with it, and then passed down the knowledge to the next generation. With the tsunami-like nature of new digital technologies, children are learning to use technology at the same time as the adults. This leads to misunderstandings and uncertainties of how technologies can or should be used. (Ribble & Bailey, 2005, p. 11)

44 http://www.digitalcitizenship.net/uploads/TeachingDC10.pdf

I propose to reframe the argument from the narrow concept of the digital divide to the concept of digital citizenship, or the capacity to participate in society online. What does it mean to be a digital citizen? Participation in society online requires regular access to information technology and the effective use of that technology. Digital citizens can be defined as those who use the Internet every day: Frequent use requires some regular means of access, some technical skill, and the educational competencies to perform tasks such as finding and using information in the web, and communicating with others.

Furthermore, digital competences have to be integrated into other subjects as well and combined with transversal competences.

Examples for the curriculum: Societal and economic impact of technology (as cross subject)
- Digital vs “analogue” society
- Interdependencies between humans and machines
- Change in self-perception (self-definition) of humans in the face of emerging technologies and robots
- Value of information and data: Commercialisation of IT services and data access
- Robots – are they the “better” workers?

Personality development in a digital society: Complementary core competences

In the last few decades, computers have posed a daunting challenge for us. In particular, in order to achieve better results, we had to learn how to adapt to the functioning of the machine. Now we are experiencing a radical change. The interaction with the system becomes increasingly natural. We can easily communicate with the systems – through our language and our gestures. Nevertheless, there are decisive differences in the communication with machines compared to the communication with humans. The relationship remains asymmetric. The dialogue is purely objective and specific in depth. A person would initiate a richer, more extensive exchange – for example, introduce more context, associations, and metaphors. Moreover, the dialogue between people includes three further levels: self-disclosure, relationship level, and appeal character.

For us humans, it will be important in the future to be able to distinguish between accessibility through language expression and the restrictions mentioned above with respect to communication levels. We will be able to interoperate with data in a new way, compensate for local data space, and navigate in hybrid worlds. For example, we will make decisions in groups in immersive data spaces. This in many ways new interaction with digital content requires new skills. AI challenges us to identify and develop our core competences. It is about raising our cognitive-emotional skills to a higher level. Highly developed skills, such as abstraction ability, generalisation, creativity, and empathy are increasingly in demand.

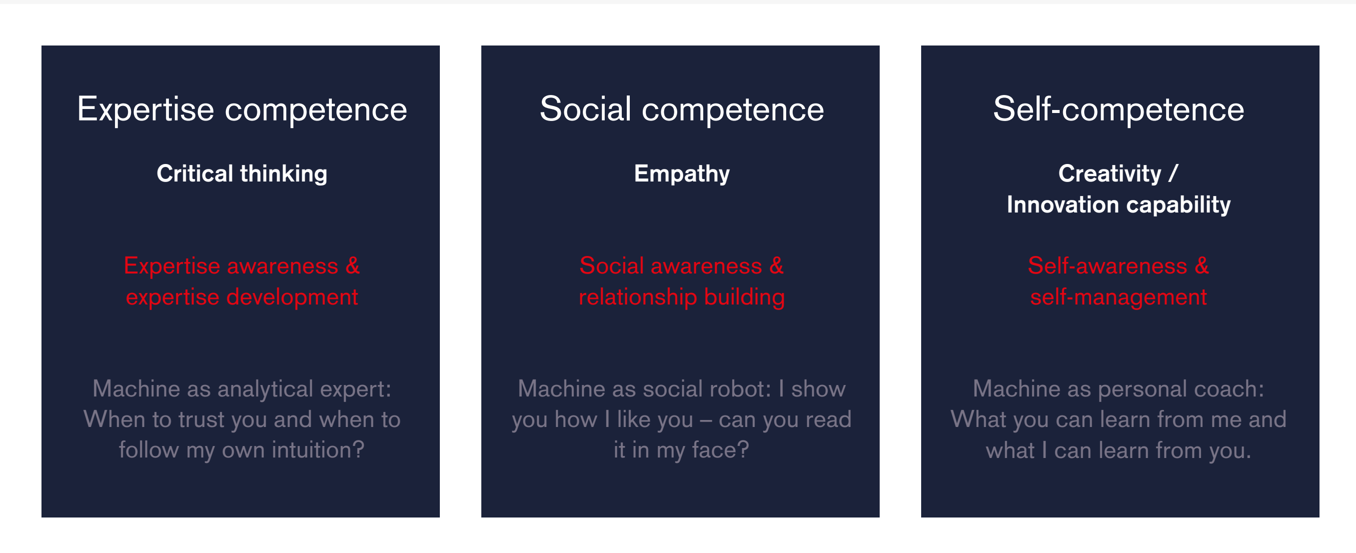


Figure 3.8. Complementary core competences of digital competences (as transversal competences)

Expertise competence: Core competence "critical thinking"

- In general: "New mind-sets and attitudes" in computational thinking
- Rethinking research: Finding the right information in huge amounts of data extremely efficiently – asking adequate questions, based on epistemological fundament
- Decision planning: Comprehensive presentation of alternatives and recommendations, with confidence levels and transparent sources, i.e., evidence-based!
- Discovery: Finding and identifying hidden connections, or recombining data from huge data spaces to create something new

Social competence: Core competence "empathy"

- The capacity to place oneself in another's position. Empathy is seeing with the eyes of another, listening with the ears of another and feelings with the heart of another
- "New mind-set" through the application of design thinking (human-centred design) in interdisciplinary settings
- Social robots will change the perceived social awareness
- Moral competence in social robots (new questions, dilemmas)
- Potential to enhance empathy through the interaction with social robots

Self-competence: Core competence "creativity, innovation capability"

- Higher order learning competences
- Experimentation and reflection
- Lateral thinking, creative thinking, divergent thinking, playful thinking
- Dealing with uncertainty, risk taking, and rule breaking
- Deliberate practice in the active maintenance of superior domain-specific performance (in spite of general age-related decline)
- New learning strategies (e.g. iML, HITL)

1.3.2

Spiral curriculum: Integration into the curriculum

Vertical integration: From primary school, sec I to sec II

I propose to emphasise the importance of key competence development. This means that the core curricula build on key competence development, an approach that can be seen in many areas of the curricula. This approach is a holistic one and should occur through the study of individual subjects in order to reach the goal of personality development. The following ideas provide examples for such key competences.

At the primary school level:

- Digital literacy refers mainly to students' capacity to increasingly source, interpret and produce texts in different formats, managing and reporting on information and becoming active readers. The ICT competence refers to more technical skills, stating the need for students to become familiar with and proficient in the operational logic of different media and platforms.
- Digital citizenship: Apart from digital etiquette, digital rights and responsibility, already starting with digital entrepreneurship: The ability to use digital media and technologies to solve global challenges or to create new opportunities (project-based learning appropriate for children at respective age level).
- Transversal competences: Already start with epistemological foundation (knowledge is not stable, asking adequate questions for search, sensitise for information evaluation).

At the secondary level I:

- Multi-literacy skills are deepened and developed further with the aim of encouraging students to engage with the material, to improve communication and to produce information across different formats.
- Digital citizenship: digital access, digital communication, digital safety (security)
- Transversal core competences: easy programming, problem solving, data and computational thinking, critical and innovative thinking, extra-curricular activities (e.g. digital entrepreneurship – start with a problem space and solve it by using design thinking mindset and process)

At the secondary level II:

- At this level, ICT competence begins to bridge students' school life with the professional world, supporting autonomous learning and inviting skills learned from outside school into the classroom. Students are asked to understand the role of ICT in society and practise transversal use of ICT across different subject matter.
- New subjects "Informatics": basic understanding of technologies (e.g. difference between automated and iML)
- Digital citizenship: digital law, digital commerce, digital health and welfare
- Transversal core competences with focus on new human-machine interaction: data and computational thinking: problem solving, data and IL.

To sum up:
As curricula are remade to suit the needs of future students, they should adopt a number of shared values also expressed within the framework such as e.g. promoting a learner-centred discourse, developing a flexible balance between the individual student and the learning community, and a transversal application of a range of skills including digital competences. A key digital competence is information literacy. The core curricula should build on key competence development with the overall goal of personality development in a digital society based on shared values. An example of such a curriculum can be found in the Appendix.

Horizontal integration: Specialities in vocational education

Vocational education is heavily influenced by the digital transformation many companies and organisations (e.g. smart government) are faced with. According to the EU framework, innovation is considered as the highest level of digital competence proficiency. The DigEuLit three-level model distinguishes three levels (Ferrari, 2012): Level I includes the basic skills, competences and approaches that are considered to be the foundation for digital competence. Level II refers to the application of digital competence within specific professional or domain contexts, where digital competence is applied to practice. Level III is about innovation and creativity, and the ability to stimulate significant change within the professional or knowledge domain.

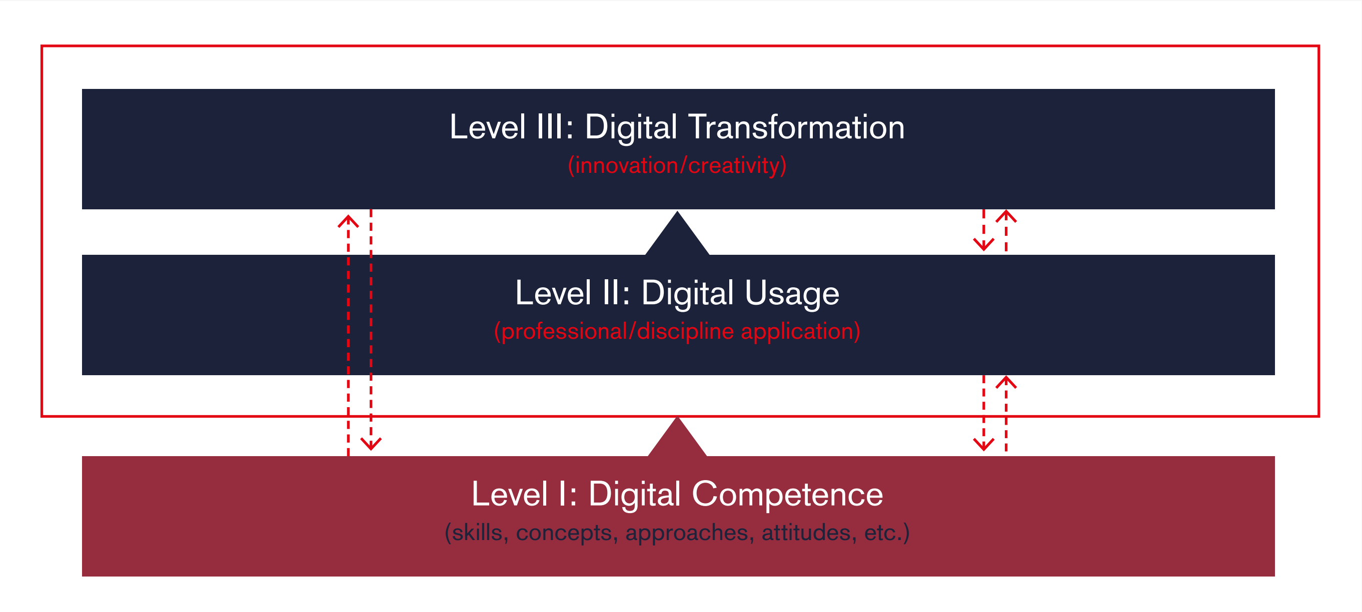


Figure 3.9. Digital competence, usage in a profession/discipline and digital transformation (Ferrari, 2012; Martin & Grudziecki, 2006)

For organisations, digital competences would embrace the competent use of digital tools and the functioning in the digital world in order to be successful in the course of digital transformation, as depicted in Figure 3.10 below.

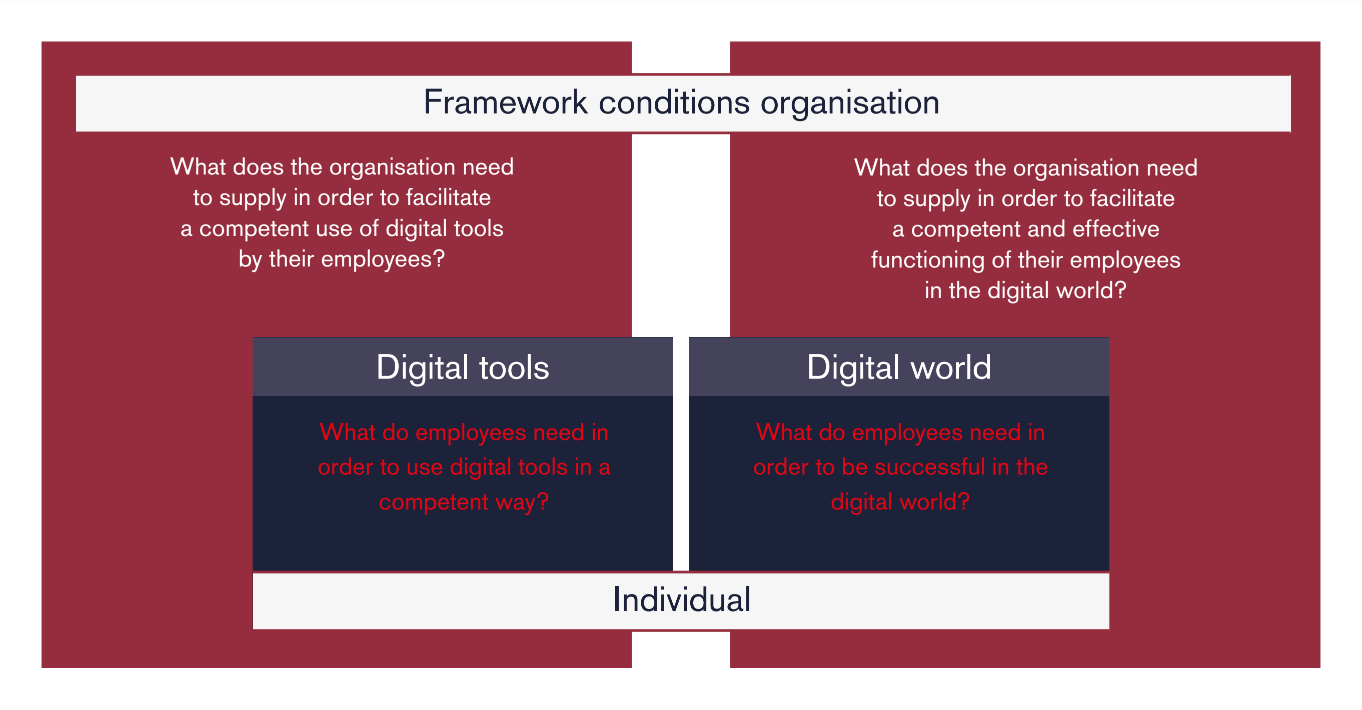


Figure 3.10. Digital competences at organisational level (in the context of digital transformation)

In vocational schools students should get prepared as soon as possible with respect to changes due to the digital transformation. Such changes may be driven by technologies such as the Internet of Things, cloud computing, Big Data, augmented and virtual reality, and AI and ML. A conceptual overview of new requirements in competences due to the digital transformation can be found in the Appendix.

Examples for the integration of digital competences as transversal competences are given in the following Table 3.2 (based on the example of vocational education and training in the commercial domain):

Existing subjects	Measures to develop a “digitally enhanced curriculum”
Economy and society	– Developing a modular concept map of thematic areas – Integrating cases in the digital context and emphasising the necessity of life-long learning, self-regulated learning as core competences – Developing/curating digital content to explain new technological advances such as Big Data for example, as well as the economic, social, ethical, legal implications for economy and society – Developing problem-based learning scenarios for current debate and implications on the commercial sector
Deepening and networking	– Developing problem-based learning scenarios for current debate and implications on the commercial sector (first focus: banks, insurance sector) – Developing interdisciplinary project work on current issues in the context of digitalisation
New subject: method-, self-, and social competences	– Learning-to-learn Competences: designing learning scenarios for selfregulated learning by using digital media – Providing instructional material, learning techniques
Do-it-yourself (DIY) learning labs	– Open space for the collaboration of students, with other learning locations – Fablabs and Marker Spaces for experimentation – e.g. developing massive open online courses (MOOCs) as team-work in specialised areas – Bridging formal and informal learning at home, school, work

Table 3.2. Examples for a “digitally enhanced curriculum” in vocational and professional education and training

Figure 3.11 presents a seamless learning and double T-Shape model as a possible framework for how a curriculum in an agile mode could be structured and developed.

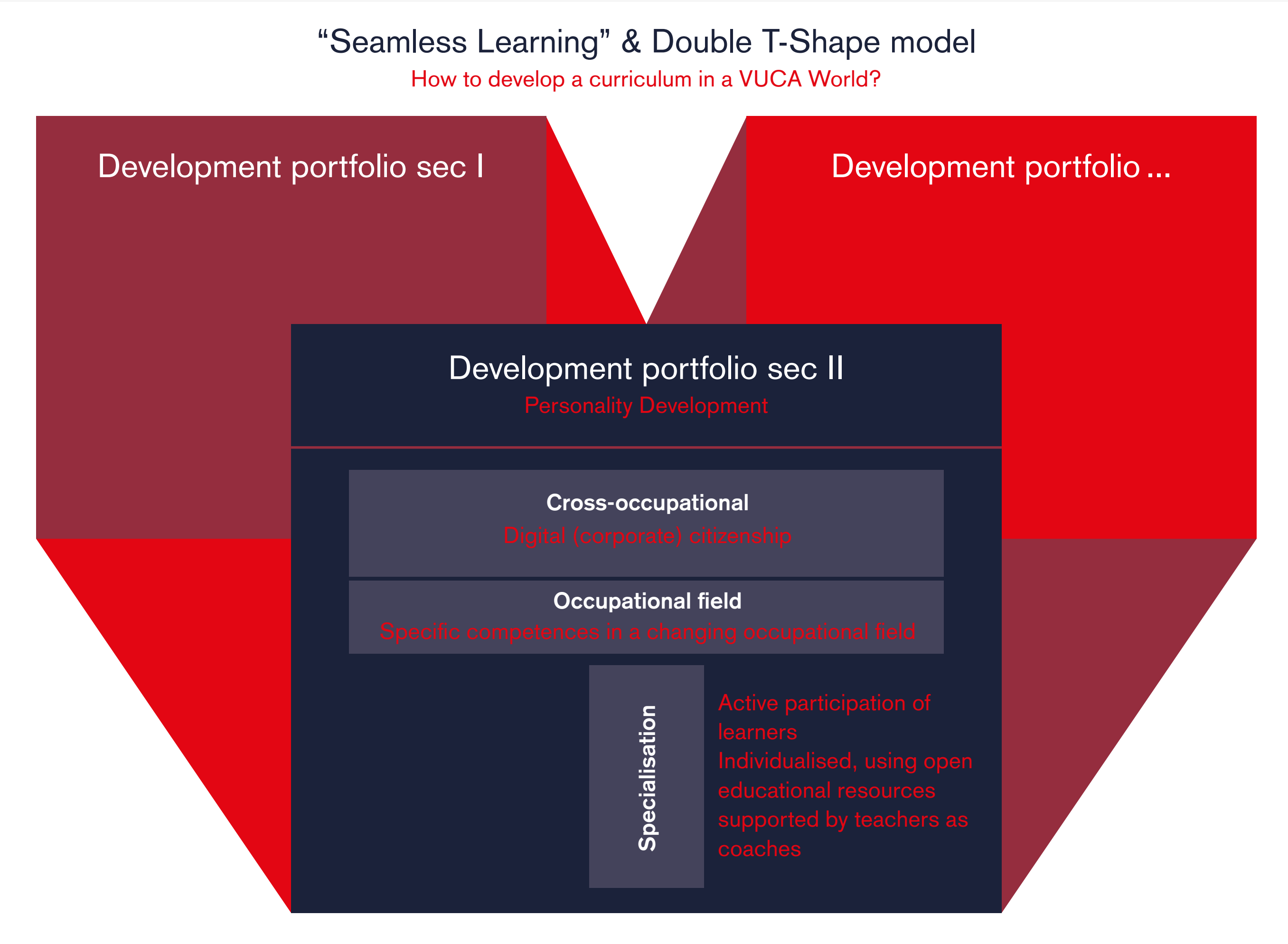


Figure 3.11. Curriculum development in vocational and professional education and training. VUCA stands for: volatility, uncertainty, complexity, and ambiguity

Horizontal integration: Specialities in higher education

The university education report 2020 of the Stifterverband für die Deutsche Wissenschaft e.V. (2016) argues for the development of digital competences as part of professional knowledge and career-oriented skills, as well as part of the personality development. However, the current discussion mainly focuses on professional and work-related skills. It is insufficient to integrate digital competences into existing study programmes purely as hard skills. Such a viewpoint provides a very technical and minimalist focus. This focus only explains how something works better. The focus should rather be on how the future of the digital world can create a work environment that is beneficial to people. A humanist educational idea is even more important than before. The most important goal for managers should be personality formation. Executives also need to understand some of the technical skills, but more important, they need to be able to solve problems, to act responsibly, and to develop their individual personalities. This type of leadership is needed.

As a result of the digitalisation, during the last few decades, creativity and empathy have been devalued (humans are underrated, Colvin, 2015). But they will be decisive for the success of tomorrow's leadership, e.g. if you want to ask the right questions or to create future designs and to make decisions responsibly.

Only this kind of person can transform the various tensions of a complex world into creative solutions. The challenge for future leaders is, on the one hand, to work on their own personality and competency formation and, on the other hand, to ensure that the entire system is developed further and that learning is possible at various levels in the organisation. Learning in the organisation becomes the top priority.

Further examples for the integration of digital competences as transversal competence are given in Table 3.3 below.

Mode	Measures to develop a "digitally enhanced curriculum"
Integration into existing subjects and programmes	– Developing a modular concept map of thematic areas as transversal competences – Developing problem-based learning scenarios for current debate and implications on decision making – "Human-in-the-loop" and "Society-in-the-loop"
Interdisciplinary project-/lab-based learning	– Developing problem-based learning scenarios for current debate and implications on the sector (e.g. health, financial sector, etc.) or on society – Digital entrepreneurship projects: The ability to use digital media and technologies to solve global challenges (e.g., climate, sustainability) or to create new opportunities – Developing interdisciplinary project work on current issues in the context of digitalisation: learning and research in Open Innovation Labs
New subjects: digital literacy skills for researchers	– Developing meta-competences for the reflection on textual norms and their interaction based on media conditions: information literacy, statistical literacy, critical thinking on research results – Providing instructional material, learning techniques for researchers
DIY learning labs	– Open space for the collaboration of students, with partners, encouraging students in extracurricular activities – Fablabs and Makerspaces for design and collaboration spaces – e.g. providing MOOCs for other students to learn digital skills, elaborating new research methods with Big Data, etc.

Table 3.3. Examples for a "digitally enhanced curriculum" in higher education

1.3.3
Constraints, limitations, and issues

The pedagogical use of digital media in schools remains constrained. As empirical studies show (e.g. ICILS 2013), dynamic and interactive pedagogical practices are not widespread in most countries and many teachers lack confidence and are sceptical about the potential of ICT to support student collaboration. A digital competence framework with transversal status in educational policy is missing. This can be regarded as a barrier. This is why discussions are progressively heading towards the development of competence frameworks not only for learners but also for educators.

The main challenge for educators, today, is to move beyond thinking of IT as a tool, or IT-enabled education platforms. Instead, they need to think about how to nurture students' ability and confidence to excel both online and offline in a world where digital media is ubiquitous. Due to their growing importance for companies and thus the commercial part of the training, vocational schools are coming under increasing pressure to address the implications of digital media for education and training. In this area, vocational schools are facing a permanent and extremely differentiated need to adapt, which is not seen in this scope or diversity in any other kind of school.

Common teaching practices are seen as a central barrier to innovation. This is because whether or not media enter the classroom depends not only on the technical prerequisites, but also on the skills and the willingness of the individual teachers to try out new forms of teaching. So far, however, school routine has been dominated by traditional forms of teaching, in which tutorials, individual and group work, and lectures are predominant. New teaching concepts, such as technology-supported, problem- or project-based forms of learning featuring shared digital notebooks or weblogs can only be integrated into such models to a limited extent.

The challenge for educational institutions consists in the appropriate use of ambidexterity and thus finding a balance between exploration of new opportunities and exploitation of existing competences. This organisational ambidexterity is often considered as a capacity or skill in itself. There is a need to communicate good examples and scale up good practices on active teaching practices and the collaborative use of ICT. The key question is how educational policy makers, leaders, and school principals can cope with potential tensions inherent in this ambidexterity and find a balance while managing this process of change.

Finally, the usage of Big Data in education (e.g. in learning analytics) also raises issues with regard to privacy, ethics, and norms. The following, non-exhaustive list highlights some of them:

Privacy:
- What data are generated by closely monitoring students' activities and who has access to these in what manner?
- Is the analysis in accordance with privacy arrangements and are the students properly informed?
- Is anonymity (hiding of student names) required for effective self-assessment?
- What are the data security issues when used as part of the grading?

Ethics:
- What are the dangers of abuse/misguided use of the data?
- If the focus is only on extrinsic motivation, then intrinsic motivation could be downsized – how to deal with the trade-off?
- "Big nudging" problems: not improving decision but manipulating – how to avoid data manipulation?
- What are the dangers of abuse/misguided use of a data-driven rule system?
- Is the risk for misinterpreting data hindering the scaffolding process by teachers?
- Is there a risk that students guided by adaptive learning systems (prediction) will develop fewer metacognitive abilities regarding monitoring and planning their own learning?

Norms:
- Are there legal data protection or intellectual property rights issues related to this kind of use of student data?
- Is social comparison inducing motivation or demotivation in students in the first semester?
- Course gamification could be merely misused by masking the terms, for example, by labelling assignments as quests and scores as experience points, without contributing to the students' learning goals.
- Problems may be caused by poor models or "over-fitting" parameter in predication learning models: sensitivity, spurious correlations, meaningless patterns, noise and classification errors (all very common problems in Big Data analytics).

1.4
Conclusions for educational policy makers

1.4.1
Raising awareness

Conclusion 1:
Broad information should focus on the major, new challenge of the fourth industrial revolution in order to uncover a possible blind spot:
Leaders, educational policy makers, have to develop a vision for the successful partnership of human and machine, with the aim to win synergy through complementary competences.

Digital transformation is not just a hype that will be over in 1–2 years. We are at the beginning of a new cognitive era. Augmentation, the human-in-the-loop and the scaled-up version of society-in-the-loop, is the key challenge of the fourth industrial revolution. Little attention has been given so far to the fact that digital competences are transversal competences.

More emphasis should be given to the use of ICT that supports active teaching practices: Innovative teaching and learning for all through new technologies and open educational resources reforms and initiatives to identify effective models for policy and institutional reform which foster systemic and sustainable change. There is a need to communicate good examples and scale up good practices of active teaching practices and the collaborative use of ICT. It should be emphasised that it is not only necessary to simply use digital tools; it is even more important to combine new digital learning forms with new competences: digital literacy and digital citizenship. However, there is a danger that the digital transformation in schools neglects future scenarios of digital competences in a broader sense (“blind spot”). There is a risk that even educated teachers are overwhelmed by the intensive and fast moving technological, social, and economic developments.

1.4.2
Curriculum development

Conclusion 2:
A national digital competence framework as a spiral curriculum with transversal educational policy status should be developed.

This framework could explicitly describe the emphasis on “digital competences 2030” across educational levels and the multiple contexts associated to their assessment. Four steps are typically recommended:

1. An operational definition for each of the digital competences is required so as to determine what should be expected from students at different age levels in terms of knowledge, skills, and attitudes. Such an operational definition can contribute to the development of a pedagogical continuum (“spiral curriculum”) for planning and assessing the learning of digital competences across age levels and subjects.

2. The connections between core subjects and digital competences should be clearly identified. The introduction of interdisciplinary themes, to be addressed within and across subjects, could contribute to the strengthening of these connections. Moreover, the interdisciplinary themes are dynamic and in continuous change, since they must reflect contemporary societal issues.

3. To assure learning about and learning with digital media, the digital competencies should be embedded within and across other transversal competences and core subjects.

4. The role of formal and informal education contexts in supporting the acquisition of digital competences needs to be acknowledged and taken into account. Strategies to closely link what is learned in and outside school should be developed.

1.4.3

Formative assessments, integrated assessment systems and graduation portfolio systems

Conclusion 3:
New ways of assessment and measurement of digital competences are needed. Enhanced formative assessments (based on national assessment banks) need to be integrated into the assessment systems. In general, the grading system in education needs a dramatic change from standardised testing to graduation portfolio systems.

The development of national frameworks should address strategies to support and regulate its implementation and the necessary assessments.

— Current assessment models, which are mostly focused on the measurement of discrete knowledge, fail to assess 21st century competences and call for new assessments grounded in authentic and complex tasks. There is the need to move towards formative assessment, regarding it as a powerful way to make students' learning visible while at the same time providing feedback that can contribute to the capacity building of both teachers and students. An example is the CBAL (Cognitively Based Assessment of, for, and as Learning, Bennett, 2010) concept for an integrated assessment system. Furthermore, automated scoring systems of open-ended items (based on AI) will probably be available in the next five years. An integrated assessment system combined with a graduation portfolio system (as applied in Singapore,[45] for example) provides a holistic view of Big Data and learning analytics in education.

— As the trend goes from programming computers to programming people (algorithms, in education: prediction models for adaptive learning), there is the danger of losing a central value in our society: self-determination. Therefore, there is a need to support informational self-determination and participation and to promote responsible behaviour of citizens in the digital world through digital literacy.

— Recent discussions around the topic of Big Data in education revolve heavily around the potential of learning analytics to increase the efficiency and effectiveness of educational processes and the ability to identify and support students at risk to reduce drop-out rates (i.e. prediction). While prediction through learning analytics is in focus, reflection on learning is neglected. Reflection refers to critical self-evaluation on the basis of own datasets created in the process of learning or (in the case of teachers/facilitators) supporting learning and datasets created by others (e.g., a teacher reflecting on his or her own teaching style based on datasets generated by the students) (Greller & Drachsler, 2012).

1.4.4

Enabling DIY learning in educational institutions

Conclusion 4:
DIY learning should be encouraged in primary, secondary, and higher education institutions. A new mindset of creativity, innovation, and self-organisation (sharing culture) should be actively fostered in order to promote school and organisational development.

Evidently, there is a need to deeply and sustainably transform teaching and learning practice in the primary and secondary schools as well as in institutions of higher education. In addition, scalability guidelines to foster the development of key competences need to be provided. In this respect, research in educational change (Hargreaves & Shirley, 2009) emphasises that this can be achieved only by involving teachers and students in the decision making process and anchoring new practices in the most promising aspects of teachers' professional knowledge.

Therefore, educational policy makers should encourage and provide the conditions necessary for the development of an effective and sustainable way to support change through transversal, dynamic and collaborative sites of DIY learning (e.g. DIY labs). Young people's efforts to create and disseminate digital media have been associated with the growing DIY movement, giving educators and students the opportunity to create, share and learn in collaboration.

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45 Singapore (highest student scores for reading, maths, and science in PISA 2015 survey), has dramatically shifted its graduation system: from standardised testing to portfolio systems. In order to graduate, students need to complete scientific investigation, literary analysis, social science research, and mathematical application, show proficiency in a world language, and finally carry out artistic performance. Renowned scientists like Prof. Darling-Hammond (2015) at Stanford University argue that the changed graduation system (the so called "Graduation Portfolio System") is one of the most important success factors of Singapore's educational system.

1.4.5

Capacity building: Digital competences of teachers

Conclusion 5:
One of the key success factors are school teachers. A major initiative for the competence development of teachers is needed. The conceptualisation and design of suitable education training measures for teachers require a systematic approach to the professional development of teachers.

Teachers addressing new digital skills such as the competent handling of online information are often entering uncharted territory in their respective fields. In this context, teachers are increasingly demanding the inclusion of media-specific qualification goals. The main challenge for educators is to move beyond thinking of IT as a tool and IT-enabled education platforms. Instead, they need to think about how to nurture students' ability and confidence to excel both online and offline in a world where digital media are ubiquitous. However, what competences teachers need to acquire remains rather vague and the discussion is mostly limited to the use and operation of computer applications and digital content media. Furthermore, it is obvious that formal seminars, such as one-day training workshops on how to use ICT, are not sufficient and effective in developing teachers' digital competences.

There is a need to encourage not just teachers' digital competences but also to encourage innovation and digital competences among institutional structures, institutions, and administrators. Policy action in key areas which guide educational practice, such as inclusion of digital material and activities in curricula design or allowing and encouraging digital assessment forms, could have a major impact.

Common teacher training practices in themselves represent a major issue and a reason why digital media teaching skills of teachers so far have been developed to a limited extent only. Like their students, most teachers informally learn how to use digital media. Teachers often simply do not have the time to attend a course or to work on a self-paced learning programme (Weiss, 2012, p. 3). School-based training courses that are tailored to the needs of a school are very widespread. However, some research studies show that even formally organised school-based events have a limited impact (e.g. Jurasaite-Harbison, 2009). Therefore, the international research literature on the education and training of teachers increasingly focuses on workplace-integrated learning and informal learning. One key finding is that formal and informal learning should be more closely interlinked for the skills development of teachers. A promising approach in particular would appear to be the search for interfaces between learning in formal and informal contexts.

Developing competences related to the use of digital media in teaching and learning therefore requires considerable efforts in vocational training and other schools. It will not be sufficient to set up a blended learning course as a one-time event. Successful support initiatives for the competence development of teachers, on the contrary, will have to be (1) rooted in their particular context and simultaneously (2) embedded in innovation strategies and quality development processes in their respective schools. In other words, curriculum development, staff training, and school development need to be aligned and coordinated in order to bring about real education reform. The development of a school culture in which students and teachers alike attach great importance to learning together and from each other is of central importance.

1.4.6
Research in the field of digital competences

Conclusion 6:
Digital competences at an organisational level need further investigation: Closing the "Society-in-the-loop" gap and learning analytics or academic analytics are examples of the new research field "digital competences at organisational level".

Interdisciplinary research for addressing the SITL gap:
An increasing number of researchers from both the humanities and computer science have recognised the SITL gap and are undertaking concerted efforts to bridge it. According to Rahwan (2016, para. 16) there is a need for new methods to research: "These include novel methods for quantifying algorithmic discrimination, approaches to quantify bias in news filtering algorithms, surveys that elicit the public's moral expectations from machines, means for specifying acceptable privacy-utility tradeoffs, and so on." Ito (2016) further elaborates that there

> would need to be a way for the public to test and audit the values and behaviour of the machines. … How machines will take input from and be audited and controlled by the public, may be one of the most important areas that need to be developed in order to deploy AI in decision making that might save lives and advance justice. This will most likely require making the tools of machine learning available to everyone, have a very open and inclusive dialog and redistribute the power that will come from advances in AI, not just figure out ways to train it to appear ethical. (Ito, 2016, paras. 8–9)

Learning analytics or academic analytics for educational institutions:
As the integrated assessment system (for professional development as well as for educational policy makers regarding the effectiveness of education) showed there are new fields for research. The terms "learning analytics" or "academic analytics" in higher education address the issue. Analytics can be a powerful tool for educational leaders and policy makers, but analytics can also increase existing value conflicts and introduce new ones. Greller and Drachsler (2012) propose that government agencies may collect cross-institutional data to assess the requirements of higher education institutes (HEI) and their constituencies.

1.5
Summary

Currently, we are facing the implications of the “Googleisierung” (Stark, Dörr & Aufenanger, 2014) on our society. Switzerland seems to be in the middle field regarding students’ computer and information competences in comparison to other EU countries. Furthermore, there is evidence that Swiss students have deficits particularly in information literacy, but the appropriate evaluation of information is already today a central fundament for civic online reasoning. “Human-in-the-loop” and “Society-in-the-loop” demand for higher-order digital competences including competences complementary to those of machines in the future.

Main statement:
Leaders, educational policy makers, must understand the connection of human and computer and develop a vision for the successful partnership of human and machine – human values and AI –, with the aim to gain synergy through complementary competences.

Conclusion 1:
Broad information should focus on the major, new challenge of the fourth industrial revolution in order to uncover the possible blind spot of augmentation, which might lead to the neglect of complementary competences and hamper a new partnership of human and machine. Switzerland should participate in the next international ICILS study in 2018 in order to obtain and have access to relevant educational data (measurement of information literacy at the secondary l level).

Conclusion 2:
A national digital competence framework as a spiral curriculum with transversal educational policy status should be developed. It is recommended to distinguish between the levels of personality development in a digital society, digital citizenship and digital literacies.

Conclusion 3:
New ways of assessment and measurement of digital competences are needed. Enhanced formative assessments (based on national assessment banks) need to be integrated into the assessment systems.

Conclusion 4:
Do-it-yourself learning (e.g. Fablabs, Makerspaces, etc.) should be encouraged in primary, secondary and higher education institutions. A new mindset of creativity, innovation and self-organisation (sharing culture, co-creation concepts) should be actively encouraged in order to foster individualised learning, personality development, and school and organisational development at the same time.

Conclusion 5:
One of the key success factors are the teachers in schools. A major initiative for the competence development of teachers is needed. The conceptualisation and design of suitable education training measures for teachers require a systematic approach to the professional development of teachers.

Conclusion 6:
Digital competences at an organisational level need further investigation: Closing the “Society-in-the-loop” gap and learning analytics or academic analytics are examples of the new research field “digital competences at organisational level”.

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Appendix 1: Further reading

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Appendix 2: Additional figures

Digital Citizenship Curriculum	K – 2			3 – 5			6 – 8			9 – 12			
	UNITS			UNITS			UNITS			UNITS			
	1	2	3	1	2	3	1	2	3	1	2	3	4
Internet Safety	●	●		●		●		●			●		
Privacy & Security	●	●	●	●	●	●	●		●			●	●
Relationships & Communication	●	●	●	●	●	●	●	●	●	●	●	●	●
Cyberbullying & Digital Drama		●		●		●	●		●	●		●	●
Digital Footprint & Reputation		●		●	●	●		●	●	●	●	●	●
Self-image & Identity				●	●	●	●	●	●	●	●		
Information Literacy	●	●	●	●	●	●	●	●	●	●	●	●	●
Creative Credit & Copyright	●			●	●		●	●	●	●		●	●

Figure 3.12. The digital citizenship curriculum, as proposed by Common Sense Media, Inc. (2017), a non-profit organisation, ranging from kindergarten (K) to twelfth grade.
Example for a digital citizenship curriculum (based on the eight WEF competences)

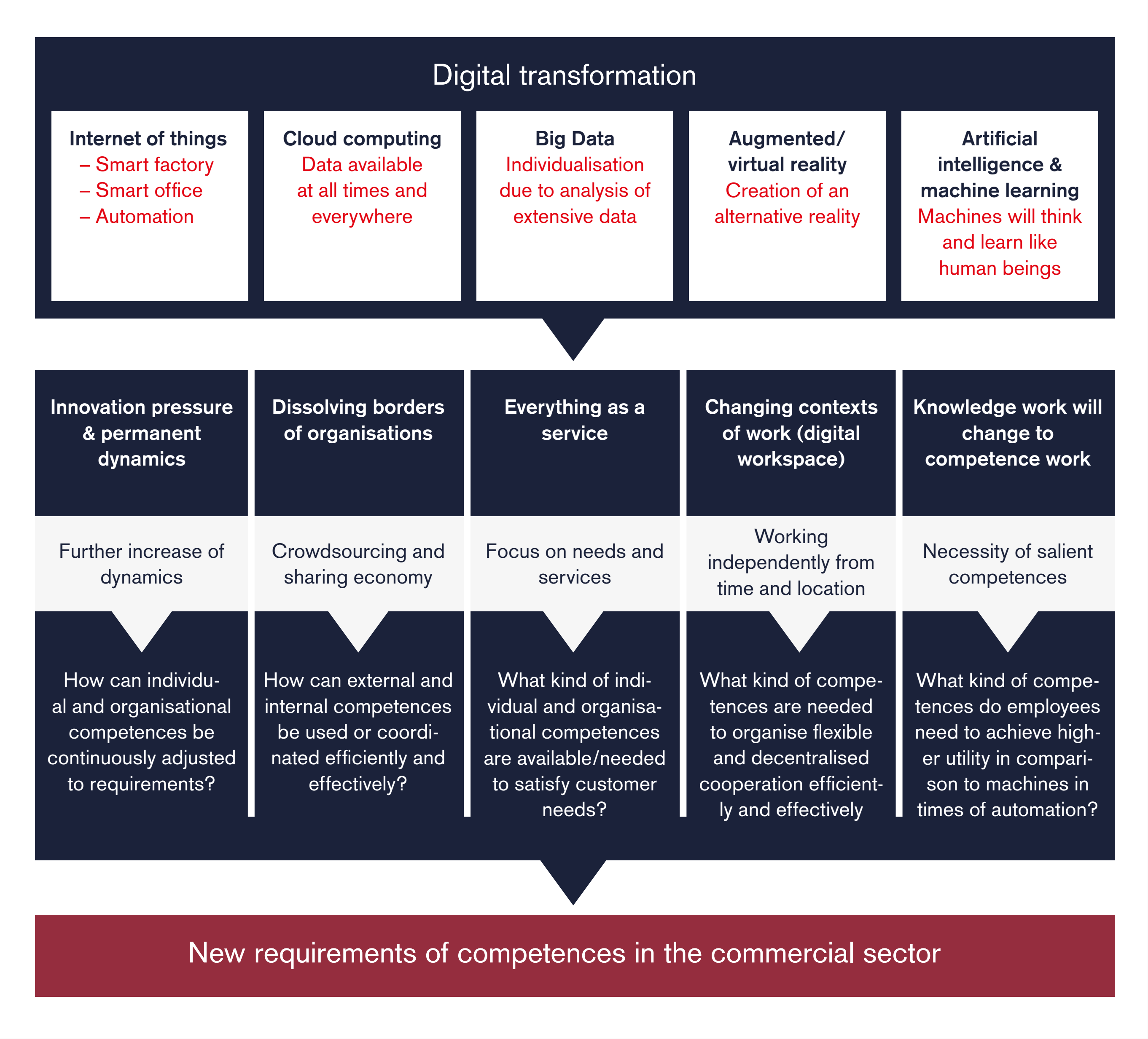

Figure 3.13. A conceptual overview of new requirements in competences for vocational school (due to the digital transformation).
New requirements of competences due to digital transformation

Imprint

Swiss Science and Innovation Council SSIC
Einsteinstrasse 2
CH-3003 Bern
T +41 (0)58 463 00 48
F +41 (0)58 463 95 47
swir@swir.admin.ch
www.swir.ch

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Swiss Science and Innovation Council SSIC
Einsteinstrasse 2
CH-3003 Bern

T +41 (0)58 463 00 48
F +41 (0)58 463 95 47
swir@swir.admin.ch
www.swir.ch