Innovation and Digitalisation of Education in Germany

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INTRODUCTION

"There is no need for 5G [high-speed Internet] on every corner." Long before the COVID-19 pandemic reached Europe, this offhand comment in March of 2019 by the German education minister led to widespread consternation.[1] Although a substantial amount of the immediate backlash came from economic circles, the import of this statement for the educational sector became starkly clear when schools were physically closed almost precisely one year later.[2] Limited or insufficient Internet access, as one element of digital inclusion, has turned out to be a significant factor in subsequent political, social, and educational developments. Access to, and the quality of, digitally-mediated remote teaching and learning have become prominent concerns. Along with Internet connectivity, inadequate digital opportunities in the form of limited hardware availability, absent infrastructure, and low levels of teachers' digital competence during the 2020 school closings have likely contributed to the current mantra to now keep schools physically open at all costs.[3] This commitment has, in turn, led to measures to facilitate educational digitalisation, backed in part by financial commitments. It has also contributed to an emerging discourse about what such digitalisation should encompass, the competences required by educators and pupils to achieve this digitalisation, and how digitalisation can be

1. N.N. 11 March 2019. Warum 5G nicht an jeder Milchkanne verfügbar sein wird. Die Zeit. (https://www.zeit.de/news/2019-03/11/warum-5g-nicht-an-jeder-milchkanne-verfuegbar-sein-wird-190311-99-327560).

2. Dalg, Paul. 24 March 2020. In der Coronakrise rächt sich der lahmende Netzausbau. Tagesspiegel. (https://www.tagesspiegel.de/wirtschaft/zu-schlechtes-internet-fuer-homeoffice-in-der-coronakrise-raecht-sich-der-lahmende-netzausbau/25676508.html).

3. Grill, Markus, and Klaus Ott. 22 June 2022. Pandemie-Maßnahmen: Das steht im "Sieben-Punkte-Plan". Süddeutsche Zeitung. (https://www.sueddeutsche.de/politik/corona-sieben-punkte-plan-lauterbach-1.5606775).

made accessible. At the same time, however, pre-existing policy conventions and cultural assumptions, combined with a long-standing lack of investment, threaten to undermine innovative initiatives hoping to capitalise on the "opportunity of the century"[4] some saw in the pandemic.

While it is too early to assess the impact of any programmes or projects that have emerged over the last two years, current trends simultaneously point towards, and away from, digitalisation and innovation in German education. Rather than attempting to be comprehensive, this article describes selected examples of technological, bureaucratic, and normative issues pertaining to educational digitalisation as illustrative of emerging trends and issues regarding both technologies themselves, and how they are embedded within policy and cultural contexts that shape their reception.

POLICY RESPONSES

Policy responses emerging from the COVID-19 disruption can be found in both theoretical and practical initiatives that highlight the oft-times radical re-thinking wrought by the events of 2020. An illustration of such a theoretical development can be found in the 2021 addendum to the 2016 strategic mission statement regarding education in the digital world, published by the standing conference of the ministers of education and cultural affairs (*Kultusministerkonferenz*) responsible for providing direction regarding federal-level educational policy. In the introduction to their paper, which addresses system-wide, school-based, and teacher education issues pertaining to digitalisation, the corporate authors refer to the impetus provided by the pandemic and the attendant digital leap forward.[5] The document highlights a contemporary understanding of the digital environment, focusing on the notion of digitality, emphasising how digital communication and interaction, and algorithmic processes inform wide-reaching societal changes.[6] In doing so, the conference heralds a shift from "…'teaching and learning with digital media and tools' to learning and teaching in a constantly changing digital reality, that is

4. Schratz, Michael. 29 March 2020. Corona-Krise: Das ver-rückte Klassenzimmer. Der Standard. (https://www.derstandard.at/story/2000116250722/corona-krise-das-ver-rueckte-klassenzimmer).

5. Kultusministerkonferenz. 2021. Lehren und Lernen in der digitalen Welt: Ergänzung zur Strategie der Kultusministerkonferenz "Bildung in der digitalen Welt". (https://www.kmk.org/fileadmin/veroeffentlichungen_beschluesse/2021/2021_12_09-Lehren-und-Lernen-Digi.pdf)

6. Felix Stalder. 2016. Kultur der Digitalität. Berlin: Suhrkamp.

recognisable as a culture of digitality, especially in cultural, social, and professional contexts and that fosters digitalisation processes" (p. 3). Shifting the focus from digital tools and media that merely facilitate participation of all learners in long-standing educational processes,[7] this new conceptualisation relies on notions of digital mediation that have largely emerged since the previous publication of the standing conference five years earlier. The *Kultusministerkonferenz* uses the framework of digitality as a lens through which to highlight issues in educational policy, school administration, professional development, and ultimately, pedagogy.

While this 2021 strategic paper thus elaborates on the implications of digitality for structural and didactic reform, it does not provide any roadmaps for pursuing systematic change. A more concrete path forward is provided by the 2020/2021 addenda to the 2019 "Digital Pact for Schools." Whereas the original digital pact intended to cover digitalisation needs up through 2024, providing 5 billion euros for schools to improve infrastructure and purchase hardware and software, the 2020 codicil uniquely addresses the human resources needed to manage these tools, by providing funding for IT administrators and their training. Even more significant than the additional 500 million euros that this subsequent digital pact added to the previously dedicated monies is the explicit emphasis on funding personnel to administer school-based hardware and software. Additional agreements also made another billion euros available for individual devices for teachers and students. While previous data indicate that teachers were already adequately equipped with personal digital devices prior to the pandemic,[8] the message sent by the latter digital pacts was an acknowledgement of the complexity of the undertaking, the need for institutional support for teachers, and the inadequate resources available to many pupils.[9]

7. Kultusministerkonferenz. 2021. Lehren und Lernen in der digitalen Welt: Ergänzung zur Strategie der Kultusministerkonferenz "Bildung in der digitalen Welt". (https://www.kmk.org/fileadmin/veroeffentlichungen_beschluesse/2021/2021_12_09-Lehren-und-Lernen-Digi.pdf).

8. GEW. 2020. Digitalpakt und Digitalisierung an Schulen: Ergebnisse einer GEW-Mitgliederbefragung (https://www.gew.de/fileadmin/media/publikationen/hv/Bildung-digital/202004-Mitgliederbefr-Digitalisierung.pdf).

9. BPV. 5 June 2020. Kommt der Systemadministrator an die Schule? (https://www.bpv.de/presse-aktuelles/pressearchiv/presse-2020/kommt-der-systemadministrator-an-die-schulen.html).

DIGITAL INFRASTRUCTURE

The digital pacts highlighted longstanding inadequacies in Germany, aptly described as being a country of "high-tech innovators, ed-tech laggards".[10] COVID-19 made it clear, despite the education minister's earlier pronouncements, that high-speed Internet is indeed a prerequisite for what has been termed emergency remote teaching.[11] In 2021, a year after the pandemic began, less than half of all schools in Germany reportedly had Internet available for students.[12] Other aspects of digital infrastructure, such as learning platforms or learning management systems, are likewise unevenly distributed.[13, 14, 15] Drawing correlations between the socioeconomic status of the schools' population and their digital infrastructure are complicated, with Rundel and Salemink describing the situation as a "geographical lottery"[16] that particularly disadvantages small and rural schools. This stands in contrast to data regarding private Internet access, which is more clearly delineated by income differences.[17] The "digital gulf" Mußmann et al. describe in relation to schools that are well-equipped and those that have limited digital infrastructure is similarly influenced by the demographics of a school's student population, but is also a result of the resources of the local school authority, the initiative of local educational leaders, and the size of the school. School form further plays a mediatory role, with students in college-preparatory gymnasia more likely to have access to digitally-mediated instruction during the pandemic than students in other school

10. Kerres, Michael. 2020. Against all Odds: Education in Germany Coping with Covid-19. Postdigital Science and Education 2. p. 690. (https://doi.org/10.1007/s42438-020-00130-7).

11. Hodges, Charles, Stephanie Moore, Barb Lockee, Torrey Trust, and Aaron Bond. 2020. The Difference between Emergency Remote Teaching and Online Learning. EDUCAUSE Review 27. (https://er.educause.edu/articles/2020/3/the-difference-between-emergency-remote-teaching-and-online-learning).

12. Mußmann, Frank, Thomas Hardwig, Martin Riethmüller, and Stefan Klötzer. 2021. Digitalisierung im Schulsystem 2021. (https://doi.org/10.3249/UGOE-PUBL-10).

13. Eickelmann, Birgit, and Kerstin Drossel. 2020. Schule auf Distanz: Perspektiven und Empfehlungen für den neuen Schulalltag. Vodafone Stiftung Deutschland. (https://www.vodafone-stiftung.de/umfrage-coronakrise-lehrer/).

14. Mußmann et al.

15. Huber, Stephan Gerhard, Paula Sophie Günther, Nadine Schneider, Christoph Helm, Marius Schwander, Julia Alexandra Schneider, and Jane Pruitt. 2020. Covid-19 - Aktuelle Herausforderungen in Schule und Bildung. Münster: Waxmann.

16. Rundel, Christina, and Koen Salemink. 2021. Bridging Digital Inequalities in Rural Schools in Germany: A Geographical Lottery? Education Sciences 11, 4. p. 181.

17. Initiative D21 e.V. 2022. D21 Digital Index 2021/2022 – Jährliches Lagebild zur digitalen Gesellschaft. (https://initiatived21.de/d21index21-22/).

types.[18] The emerging data highlight the fact that even neighbouring schools operate in exceedingly different contexts from one another. While one school might have individual tablets for every student and teacher, able to take advantage of wireless data transfers and cloud-based networks,[19] other schools have severely limited Internet capabilities and neither devices nor applications to support teachers' and pupils' integration of online resources.[20] Other institutions have implemented "bring-your-own-device (BYOD)" policies that variously offer centralised support or benign neglect, largely ignoring issues of individual accessibility, system security, or educational appropriacy. In such varying contexts, the nuances of who has access to what, and in what quality, make it difficult to characterise the current state of affairs. These differences also pose a significant challenge to attempts at developing and implementing appropriately targeted and relevant initiatives.[21]

Although improvements to infrastructure are often associated with lengthy bureaucratic processes and slow implementation, initiatives to provide digital access to schools since the beginning of the pandemic have demonstrated the potential of rapid response in some cases. While 52 per cent of teachers reported having adequate digital infrastructure in schools in 2020, this number jumped to 61 per cent only a year later.[22] In many cases, the emphasis has been on establishing access to servers, hosting platforms, and communication systems. Widely reported, for example, was the 72-hour marathon in Baden-Württemberg that resulted in almost 4000 primary and secondary schools being connected to a server and a learning management system over the course of one weekend.[23] In Lower Saxony, a statewide school cloud was pressed into action a few weeks later and a year ahead of schedule.[24] Between 2018 and 2021, the use of learning platforms among German

18. Eickelmann and Drossel.

19. Roenneke, Dominik. 6 May 2022. Ein Beispiel macht Schule: Monheim am Rhein. (https://www.professional-system.de/education/ein-beispiel-macht-schule-monheim-am-rhein/).

20. Krein, Ulrike. 2022. 'Hätten wir keinen Digitalpakt, hätten wir eine bessere Ausstattung': Schulische Infrastruktur zwischen politischen Versprechungen und netzfreier Realität. Medienpädagogik Zeitschrift für Theorie und Praxis der Medienbildung 49.

21. Ibid.

22. Mußmann et al.

23. Neuner, Sebastian. 2 February 2022. Moodle für BW in 72 Stunden. (https://media.ccc.de/v/meetup-2021-01-114-moodle-fr-bw-in-72-stunden).

24. Gütsel Online. 10 October 20. HPI-Schul-Cloud geht in Regelbetrieb Über und verlässt das HPI. (https://www.guetsel.de/content/23604/2524420.html).

teachers increased from 12 per cent to 58 per cent.[25] These examples are evidence of timely innovation and rapid crisis responses.

While these developments are dramatic and suggest that the pandemic might be "a real game changer",[26] there are other indications that these innovations are not sustainable. In fact, in some cases, gains in access made during the early days of the pandemic have been rolled back. In Baden-Württemberg, over five thousand schools – 80 per cent of whom gained online access during the aforementioned 72-hour undertaking – have been notified that their connections via the state-subsidised network will be rescinded by 2023, with only costly and incompatible commercial alternatives suggested in its stead.[27] Such administrative wrangling not only slows the momentum that the pandemic provided; it actively thwarts any gains made in the last two years. The technological harm that results is mirrored by pedagogical resignation on the part of school leaders and educators who devoted substantial efforts to acquiring the competences necessary to implement digitally-mediated teaching and learning.

DATA PRIVACY CONCERNS

Continued lack of clarity regarding the legality of particular tools likewise reveals how the promise of the pandemic, in terms of digital innovation, is threatened. Arising in response to the misuse of data during its fascist and communist eras – empowered by new technologies of the time – concerns regarding data privacy in Germany are historically rooted. Individuals and bureaucracies are thus exceedingly cautious with regard to potential abuses of data.[28] The reticence regarding data use is compounded by European data privacy regulations, which are interpreted narrowly and applied broadly in the German educational context.[29] Germany funds

25. Mußmann et al. p. 239.

26. Kals, Ursula, and Sarah Obertreise. 18 September 2021. 'Ein echter Gamechanger'. Frankfurter Allgemeine.

27. Heise Online. 12 June 2022. Landeshochschulnetz Belwü: Netzzugänge für Schulen im Ländle vor dem aus. (https://www.heise.de/news/Landeshochschulnetz-BelWue-Netzzugaenge-fuer-Schulen-im-Laendle-vor-dem-Aus-7137907.html).

28. Buntins, Katja, Svenja Bedenlier, Melissa Bond, Michael Kerres, and Olaf Zawacki-Richter. 2020. Mediendidaktische Forschung aus Deutschland im Kontext der internationalen Diskussion. Eine Auswertung englischsprachiger Publikationsorgane von 2008 bis 2017. In: Reinhard Bauer, Jörg Hafer, Sandra Hofhues, Mandy Schiefner-Rohs, Anne Thillosen, Benno Volk. and Klaus Wannemacher (eds.). Vom e-learning zur Digitalisierung: Mythen, Realitäten, Perspektiven. Münster: Waxmann.

29. Kerres, Michael. 2020.

its data protection authorities with 85.7 million euros annually at a rate seven times the European average of 12.1 million euros.[30] While this discrepancy can stem from a variety of circumstances, its size offers some indication of the awareness that exists regarding issues of data privacy in Germany compared to its neighbours. This sensitivity has resulted in the rejection or reluctant toleration of digital platforms, tools, and videoconferencing services, or cloud-based applications, especially those located outside of the European Union. The impact on digitalisation in schools has been significant, with concerns about data privacy perceived to outweigh ones regarding functionality.[31]

While some German states have made allowances due to the COVID-19 situation, lifting restrictions on the use of nonconforming applications, these exceptions are frequently labelled with expiration dates with varying degrees of flexibility.[32, 33] This generates substantial uncertainty among administrators who are tasked with determining whether a particular digital tool conforms to data privacy regulations,[34] and who need to decide whether to invest time and money in purchasing licenses or equipment that may be disallowed in the near future, and for training and management processes that need to be developed and potentially ultimately discarded. Fears of committing to a system that will subsequently have to be abandoned raise implementation barriers at the school level. Teachers are likewise inhibited by this state of affairs, reluctant to invest their sparse time and energy in temporary peda-

30. Chander, Anupam. Meaza Abraham, Sandeep Chandy, Yuan Fang, Dayoung Park, and Isabel Yu. 202. Achieving Privacy: Costs of Compliance and Enforcement of Data Protection Regulation. World Bank's World Development Report 2021 Team in collaboration with the Macroeconomics, Trade and Investment Global Practice. Policy Research Working Paper No. 9594. p. 28. (https://scholarship.law.georgetown.edu/facpub/2374).

31. Denker, Bastian, Nikolai Horn, and Tim Vallée. May 2021. Datenschutz und Digitale Schule: Impulse zur Entlastung und Unterstützung von Schulen. Forum Bildung Digitalisierung. (https://www.forumbd.de/publikationen/impulspapier-datenschutz-und-digitale-schule/).

32. Krempl, Stefan. 4 March 2021. Rheinland-Pfalz: Schulen dürfen Microsoft Teams länger nutzen. (https://www.heise.de/news/Rheinland-Pfalz-Schulen-duerfen-Microsoft-Teams-laenger-nutzen-5072486.html).

33. News4Teachers. 27 June 2022. Hubig verbietet Schulen, die Microsoft-Software Teams zu nutzen (den Berufskollegs aber vorerst nicht) – CDU: „verstörend". (https://www.news4teachers.de/2022/06/hubig-verbietet-schulen-die-microsoft-software-teams-zu-nutzen-berufskollegs-aber-vorerst-nicht-cdu-verstoerend/).

34. Moir, Joshua and Michael Wrase. 29 January 2022. Rechtliche Anforderungen an den digitalen (Distanz-)Unterricht von Schulen (Parlamentarischer Beratungs- und Gutachterdienst des Landtags Nordrhein-Westfalen). (https://www.landtag.nrw.de/portal/WWW/dokumentenarchiv/Dokument/MMI17-355.pdf).

gogies, especially in light of generally overwhelming obligations.[35] The majority feels inadequately supported by educational authorities in regard to issues of data privacy and data security, and the practice of relying on school-based laypersons to supervise data management practices is inadequate.[36] Anxiety regarding potential legal recourse if teachers use a tool for which approval has been withdrawn is compounded by the supposed individual responsibility they bear in this regard and the lack of consistent and clear communication regarding individual tools or uses.[37]

The situation is further muddied by the autonomy of the German states – again a result of its history – each of whom has its own data protection agencies and state educational authorities that do not necessarily cooperate closely intrastate, and have historically had little incentive or recourse to do so interstate.[38] This situation is slowly changing, with growing recognition that the necessary investment of fiscal resources and expertise to develop sound digital solutions is beyond the capacity of individual states.[39] Generally, a lack of clear guidance hampers efforts to introduce digital innovations, with one educational official tasked with assessing data privacy concerns in relation to digitally-mediated initiatives arguing that he could not approve *any* applications for the integration of digital tools, since there was no written policy for his state upon which to base such a decision.[40]

The situation regarding digital devices for educators exemplifies the dilemmas raised by digitalisation and data security. In recognition of the fact that teachers' use of private devices for professional purposes meant that teachers were storing protected data on unregulated computers, many schools used the funding provided by the second digital pact to outfit educators with laptops for school-related business, as was intended by the monies and recommended by data protection experts. However, due to concerns about data security, the official laptops and tablets

35. Cordes, Michael, Klaus, Hurrelmann, and Selin Tüysüz. 2022. Wie belastet sind die Lehrkräfte in Berlin? Eine Studie zur Arbeitssituation und zum Bedarf an professioneller Unterstützung. FiBS-Forum No. 77. (http://hdl.handle.net/10419/251769).

36. Denker, Bastian, Nikolai Horn, and Tim Vallée.

37. Wawrzyniak, Jessica. 23 June 2020. Datenschutzverstöße im Homeschooling und Bußgelder. (https://digitalcourage.de/blog/2020/datenschutzverstoesse-im-homeschooling-und-bussgelder).

38. Wollmann, Hellmut. 2020. Entwicklungs- und Konfliktlinien des Bildungssektors im deutschen Föderalismus: Neue Dynamik durch Digitalisierung in Zeiten des Coronavirus? In: Wolfgang Roters, Horst Gräf, and Hellmut Wollmann (eds.). Zukunft denken und verantworten. Wiesbaden: Springer Fachmedien. pp. 253–283.

39. Bitkom Research GmbH. 2020. Last call: Germany! Die Bitkom-Digitalstrategie 2025. (https://www.bitkom.org/Bitkom/Bitkom-Digitalstrategie2025).

40. Personal communication. 2022.

were restricted to a small selection of approved applications, or secured to prevent teachers from customising their devices – or both.[41] Questions regarding responsibility for administration and updates, as well as training, frequently remain to this day unresolved.[42] Given the lack of functionality, teachers have quickly resorted to using their private devices. With regard to data security, the tension between practicality and safety is indicative of the challenges faced in regard to educational digitalisation and innovation.

At the same time, these dilemmas have been drivers of innovation, leading to the kind of educational technology investments and advancements that were slow to be adopted pre-pandemic. In response to the problematic nature of many commercial applications, for example, open source and European alternatives to digital tools from outside the European Union have flourished in both development and acceptance. While some of these applications were available prior to 2020, interest in them was limited. In the interim, both internationally recognised open source products and small-scale innovations have become widely known and welcomed. Learning management systems and video-conferencing systems are only two examples of open source projects that have gained widespread traction in schools and universities. Alternatives to commercial tools for collaboration have been developed both under the aegis of state-led agencies and by individuals or small teams at a grassroots level. While the latter are increasingly making their source code publicly available for transparency and adaptation, many of the former are restricted to use in one German state. This is the case both with "BiParcours",[43] only available for educational purposes in North Rhine-Westphalia, and the "Online-Pinnwand Schleswig-Holstein",[44] developed as an alternative to a commercial bulletin board tool. While these tools address the problem of data privacy on the one hand, they inadvertently underscore the way in which the federal system acts as an obstacle to innovation on the other.

In response to the challenges faced by school leaders and teachers in having to individually assess every application and the contradictory assessments of

41. Blume, Bob. 7 March 2021. Diskussion: Wir sind es nicht wert. (https://bobblume.de/2021/03/07/diskussion-wir-sind-es-nicht-wert/).

42. Krauß, Bärbel. 12 February 2022. Müssen Lehrer im Land ihre Laptops Ende 2022 zurückgeben? Stuttgarter Zeitung. (https://www.stuttgarter-zeitung.de/inhalt.digitalpakt-problem-in-baden-wuerttemberg-muessen-lehrer-im-land-ihre-laptops-ende-2022-zurueckgeben.77d8a4dd-ea2e-4946-ac66-d4b1827834c6.html?reduced=true).

43. Bildungspartner NRW. Biparcours. (https://biparcours.de/).

44. IQSH. Online-Pinnwand Schleswig-Holstein. Institut für Qualitätsentwicklung an Schulen Schleswig-Holstein. (https://opsh.lernnetz.de/).

educational and data privacy agencies within and between states, the German Federal Ministry of Education and Research in 2021 provided funding for the research project "Directions: Data Protection Certification for Educational Information Systems",[45] which has as its goal a voluntary certification process for software based on consistent criteria related to data privacy and data security. This is complemented by "EduCheck Digital" (EDCD),[46] a project designed to develop consistent standards and evaluation processes, specifically for educational applications, with regard to legal, technical, and accessibility guidelines. Funded by the aforementioned digital pacts with monies designated for all sixteen states, the initiative is an illustration of how their unified efforts in a federal system can spur innovation through cooperation.

ARTIFICIAL INTELLIGENCE

Another area that is affected by the scepticism towards data is in the development or use of artificial intelligence (AI) for educational purposes. More accurately defined by one of a number of underlying processes, including machine learning, deep learning, or natural language processes, the reliance of AI on user data has led to its reluctant acceptance as an educational technology – not just in Germany. Rather, public awareness of the potential uses and misuses of AI is growing internationally. In 2021, the European Union proposed guidelines on the ethical use of AI which, if implemented as drafted, would impose significant restrictions on the use of AI, specifically as it pertains to minors.[47] Analogous to the European general data privacy regulations (GDPR) in both its informed awareness of the risks of new technologies and its potential inhibitory effect on innovation, the regulations seek to balance technological prowess with individual self-determination.[48] Educational data mining, learning analytics, adaptive applications, and intelligent tutoring systems rely on similar or overlapping underlying processes with different emphases.

45. Directions: Data Protection Certification for Educational Information Systems. (https://directions-cert.de/).

46. EduCheckDigital. (https://educheck.schule/).

47. European Commission. 21 April 2021. Regulatory Framework Proposal on Artificial Intelligence. (https://digital-strategy.ec.europa.eu/en/policies/regulatory-framework-ai).

48. Holmes, Wayne, Kaska Porayska-Pomsta, Ken Holstein, Emma Sutherland, Toby Baker, Simon Buckingham Shum, Olga C. Santos, Mercedes T. Rodrigo, Mutlu Cukurova, Ig Ibert Bittencourt, and Kenneth R. Koedinger. 2021. Ethics of AI in Education: Towards a Community-Wide Framework. International Journal of Artificial Intelligence in Education. (https://doi.org/10.1007/s40593-021-00239-1).

As such, the concerns related to them reflect common themes, but also necessitate individualised responses. Whereas data mining applications, for example, raise foremost questions of privacy, adaptive applications relying on such data have the potential to individualise learning materials in ways that can influence educational trajectories. These need to be considered, not just from generic ethical perspectives, but in the context of the purposes of education in democratic contexts. Transparency, privacy, automated decision-making, biased algorithmic models, data accumulation, and user consent are all issues that pertain specifically to educational AI.[49] In light of the complexity of AI as a technology and the implications for teaching and learning environments, Germany's federalism and its conservative attitudes towards data collection and application have contributed to the slow pace of innovation in this area.

Despite these reservations, however, research groups working on AI for educational purposes have garnered more attention in the last few years. Motivated initially by the challenges of individualising instruction adequately for increasingly diverse pupil populations, a further impetus emerged in the wake of COVID-19. Several things came together at this juncture that have led to a comparative boom in this area. Firstly, emerging recognition of the appropriate roles of AI in the classroom has allayed dystopian fears of robots as teachers. Instead, there has emerged a consensus around the "didactic perspective, resting on scientific consensus, that AI-supported systems are not to be implemented as a replacement for physical presence in classrooms, but rather in supportive or complementary ways ("Co-teaching" and "assisted learning" in hybrid learning situations and flipped-classroom settings, etc.)" (Translation by the author).[50] More palatable from both a humanistic and technological perspective, an emerging understanding of AI's capabilities and limitations recognises its roles in supporting educators in what they currently do: Use different kinds of data to identify learners' needs and address them in pedagogically appropriate ways.[51] Secondly, many teachers' experiences in the early stages of the pandemic revealed that expectations regarding feedback surpassed their

49. Ibid.

50. Schmid, Ulrich, Berit Blanc, and Michael Toepel. 2021. KI@Bildung: Lehren und Lernen in der Schule mit Werkzeugen künstlicher Intelligenz – Schlussbericht. Deutsche Telekom Stiftung. (https://www.telekom-stiftung.de/sites/default/files/files/media/publications/KI%20Bildung%20Schlussbericht.pdf).

51. Blume, Carolyn, Lisa Middelanis, and Torben Schmidt. In preparation. Where Tasks, Technology, and Textbooks Meet: An Exploratory Analysis of EFL Teachers' Perceived Affordances of an ILTS. In: Almut Ketzer-Nöltge and Nicola Würffel (eds.) Lehrwerke 4.0. Berlin: Peter Lang.

capacity to design, assign, evaluate, and respond to the largely written work that pupils were completing in record speeds at their desks at home. With schooling reduced to a few videoconferences a week at most, educators and parents resorted to more conventional ideas about schooling, relying on (digital or analog) exercises and assignments that pupils complete more or less independently, and more or less quickly, and submit for teachers' feedback.[52] Various studies indicate a significant desire among pupils and parents for feedback, an expectation that was met by teachers to varying degrees. While Helm and Huber report that pupils in Germany, Austria, and Switzerland agreed or strongly agreed with the statement that their teachers provided feedback and checked their work approximately half of the time (mean = 3.23 out of 6), the standard deviation of 1.17 suggests that a wide range of feedback practices could be found[53], a finding corroborated by Wacker et al. in a separate survey.[54] At the same time, there was a significant correlation between whether teachers engaged in these practices and pupils' perceptions of the quality of their emergency remote learning experiences.[55] Data from Eickelmann and Drossel corroborate the impression that addressing pupils' assignments was a key issue in the early weeks of the pandemic, with the German teachers in their study indicating that they felt most overwhelmed during this time by the need to give feedback to their pupils (62.3 per cent) and check their work (59.4 per cent), the two items named most frequently.[56]

These experiences may have contributed to a greater receptivity to automated processes for comparatively simpler exercises and assignments that best lend themselves to AI support. Intelligent tutoring systems for secondary English language learning (Feedbook) and maths (bettermarks) are two applications developed for the German school sector. Initiated prior to the pandemic, both projects saw

52. Wößmann, Ludger, Vera Freundl, Elisabeth Grewenig, Philipp Lergetporer, Katharina Werner, and Larissa Zierow. 2020. Bildung in der Coronakrise: Wie haben die Schulkinder die Zeit der Schulschließungen verbracht, und welche Bildungsmaßnahmen befürworten die Deutschen? IFO Schnelldienst 73, pp. 25–39. (http://hdl.handle.net/10419/225170).

53. Huber, Stephan Gerhard, and Christoph Helm. 2020. Lernen in Zeiten der Corona-Pandemie Die Rolle familiärer Merkmale für das Lernen von Schüler*innen: Befunde vom Schul-Barometer in Deutschland, Österreich und der Schweiz. In: Detlef Fickermann and Benjamin Edelstein (Eds.). „Langsam vermisse ich die Schule …" Schule während und nach der Corona-Pandemie. DDS – Die Deutsche Schule. No. 16, pp. 37–60.

54. Wacker, Albrecht, Alexander Unger, and Thomas Rey. 2020. „Sind doch Corona-Ferien, oder nicht?" Befunde einer Schüler*innenbefragung zum „Fernunterricht". In: Detlef Fickermann and Benjamin Edelstein (Eds.). „Langsam vermisse ich die Schule …" Schule während und nach der Corona-Pandemie. DDS – Die Deutsche Schule. No.16, pp. 79–94.

55. Huber, Stephan Gerhard, and Christoph Helm.

56. Eickelmann and Drossel.

increased interest as a result of the need for digital tools to bridge the physical distance between teachers and pupils.[57] Developed in cooperation with computational linguists, educational psychologists, and experts in digitally-mediated English language learning with funding provided by the German Federal Ministry of Education and Research, FeedBook is currently being tested in three states with over 1000 participants.[58] Bettermarks is a commercial product currently available without cost to schools in seven German states and German overseas schools.[59] While bettermarks began development in 2008, with initial evaluation studies published in 2014,[60, 61] it is only since the 2020/2021 academic year that these cooperations have been established, highlighting the changes in attitudes and needs that the pandemic fostered. With its embedding in various learning management systems or learning platforms, it also illustrates the need for fundamental technologies to enable integration.

CONCLUSION

The COVID-19 pandemic illuminated for public audiences long-standing problems regarding digitalisation in German schools and universities. What appears at first glance to be a technological issue of inadequate infrastructure that can be resolved with substantial monies, a closer look reveals the ways in which political and educational systems contribute to this state of affairs. These systems in turn are informed by attitudes arising from historical experiences as they encounter rapid changes in fundamental political, economic, cultural, technological and public health realities.

57. Spitzer, Markus Wolfgang Hermann, and Sebastian Musslick. 2021. Academic Performance of K-12 Students in an Online-Learning Environment for Mathematics Increased During the Shutdown of Schools in Wake of the Covid-19 Pandemic. PloS One. 16, 8. e0255629.

58. Parrisius, Cora, Ines Pieronczyk, Carolyn Blume, Katharina Wendebourg, Diana Pili-Moss, Mirjam Assmann, Sabine Beilharz, Stephen Bodnar, Leona Colling, Heiko Holz, Lisa Middelanis, Florian Nuxoll, Julia Schmidt-Peterson, Detmar Meurers, Benjamin Nagengast, Torben Schmidt, and Ulrich Trautwein. 2022. Using an Intelligent Tutoring System within a Task-Based Learning Approach in English as a Foreign Language Classes to Foster Motivation and Learning Outcome (Interact4School): Pre-registration of the Study Design. PsychArchives. (10.23668/psycharchives.5366).

59. Bettermarks. bettermarks GmbH. (https://de.bettermarks.com/).

60. Daberkow, Andreas, and Oliver Klein. 2014. Yes, it's Possible – Online Mathematics for First-Semester Students. Fifth National Workshop and Conference – Technology and Innovation in Maths Education. (https://journal.ph-noe.ac.at/index.php/resource/article/view/152/157).

61. Scharnagl, Susanne, Petra Evanschitzky, Judith Streb, Manfred Spitzer, and Katrin Hille. 2014. Sixth Graders Benefit from Educational Software When Learning About Fractions: A Controlled Classroom Study. Numeracy 7, 1.

The resulting tensions, seen in initiatives that facilitate digital innovation and circumstances that hinder it, make it difficult to describe the current situation in broad strokes. Moving forward, microanalyses of particular contexts can provide a fuller understanding of the ways in which digital innovation is mediated by federal, state, and local conditions.

What remains constant regardless of differences due to socioeconomic, demographic, or attitudinal factors are the necessary elements for successful digital innovation in the educational sector. As can briefly be shown in the preceding examples, policy initiatives must be both broad enough to encompass far-flung expertise and economies of scale, and precise enough to reflect local priorities. The ability of school leaders and teachers to rely on state agencies with regard to infrastructure and legal ramifications vis-à-vis educational platforms or tools is likewise of paramount importance if they are to invest professional and fiscal resources into the development of administrative systems, pedagogical procedures, or didactic scenarios for these applications. Realistic solutions for the thorny issues raised by data privacy or AI cannot be developed on a teacher-by-teacher basis, but need to be addressed by experts who understand the ways in which educators have always – and continue to – considered the potential benefits or problems associated with a pedagogical approach, regardless of the medium. At the same time, teachers need to be empowered to understand the ramifications of these particular media, addressing both underlying beliefs and attitudes and digital-pedagogical competences.

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