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**DIRECTORATE FOR EDUCATION AND SKILLS  
EDUCATION POLICY COMMITTEE****Education 2030 - Curriculum analysis: Literature review on managing time lag and technology in education****The Future of Education and Skills: Education 2030****6<sup>th</sup> Informal Working Group (IWG) meeting  
23-25 October 2017  
Paris, France**

*The IWG members are invited to:*

- *NOTE the preliminary findings from the literature review on managing time lag and technology in education*
- *DISCUSS how these preliminary findings can be used to further refine the "design principles" in curriculum re-design that endure across time, across different countries, and across different thematic challenges from the literature review on managing time lag and technology in education*

This paper includes:

- Section 1 - Conceptualizing time lag dilemma in curriculum change – An exploration of the literature by Joke Voogt (University of Amsterdam) & Nienke Nieveen (Eindhoven University of Technology, Netherlands Institute for Curriculum Development)
- Section 2 - Technology in Education: Effects, affordances and conditions for effective implementation - A review of recent literature by Joke Voogt, Karmijn van de Oudewetering (University of Amsterdam) & Henk Sligte (Kohnstamm Instituut)

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## *Conceptualizing time lag dilemma in curriculum change – An exploration of the literature*

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### **1. Introduction**

This literature study is a follow-up of the formal literature review *The impact of Curriculum Reform: A review of the literature* (Voogt, Nieveen, Sligte & Lemmens, 2016) ([EDU/EDPC/RD\(2016\)39](#)) conducted for the Future of Education and Skills: the OECD Education2030 and presented at the 4th informal working group, November 9-10, 2016 in Beijing. Based on the discussion of the review it was concluded that:

- The literature review was well-received and provided insight in many aspects of curriculum reform; and as such informs the Education2030 project.
- The review did not provide new insights about curriculum overload and the time lag dilemma associated with curriculum reform at the national level.
- The literature review was limited because of the (deliberately) chosen criteria for the selection of articles to be included: peer-reviewed articles written in the English language.

For these reasons a follow-up literature study was requested on curriculum overload and time lag dilemma, which would focus on other literature than peer reviewed articles only, including non-English references. Countries have been asked to submit suggestions of possible studies to the secretariat. A literature review on curriculum overload (Voogt, Nieveen & Klöpping, 2017) was presented at the 5th informal working group, May 17-18, 2017 in Lisbon. The current review addresses the issue of time lag.

Curriculum development can be perceived as the permanent search for qualitative improvement for relevance, in response to changes in society (Bude, 2000). However, when new social, economic and individual needs on education are identified, the changes in education are likely to fall behind the changes taking place in the real world. This problem is referred to as the time lag dilemma, and is considered a challenge of the curriculum reform agenda. Countries are searching for approaches to anticipate in the curriculum on changes in society as well as the effects of such approaches.

The main purpose of the follow up study is to broaden our understanding of knowledge about the impact of curriculum reforms in jurisdictions (national, provincial, state), in particular focusing on how jurisdictions deal with the issue of time lag taking into account how the curriculum is regulated in different jurisdictions.

The following question guides this review: Which elements in curriculum planning and enactment contribute to time lag and how is time lag handled in curriculum development processes?

In the next section (2) we describe the approach we used to find the studies for this review. In section 3 we present the results of the review and in section 4 we discuss these findings.

## 2. Methodology

The search for relevant publications started with looking for studies concerning the time lag dilemma in scientific datasets (i.e. Education Resources Information Center (ERIC) and Web of Science). This resulted in one publication in the English language on engineering education in higher education concerning curriculum planning at the level of university programs (Desha, Hargroves & Smith, 2009). The article presented some interesting conceptual ideas about emerging elements of planning for rapid curriculum renewal, in particular useful for planning curriculum renewal at school level. In addition we also tried to find relevant publications with the term time lag dilemma using less sophisticated databases (Google and Google Scholar). This resulted in one additional publication, also in the field of engineering (UNESCO, 2010).

To find literature that may inform us about the time-lag dilemma we consulted our network to find additional studies. We received a white paper from the National Council for Curriculum and Assessment (NCCA, 2017) that discusses the time lag issue explicitly. In addition we deliberately looked for studies that describe/analyze curriculum renewal processes that explicitly deal with current societal challenges. This resulted in 21 publications, which were used for this study. Table 1 provides an overview of the type of publications in our dataset. Table 2 provides an overview of the year of publication of the studies in the dataset.

**Table 2.1. Overview of the type of publications in the dataset**

Type of publication	N
Peer-reviewed journal articles	9
Scientific books	3
Reports/ proceedings	9

**Table 2.2. Year of publication of the studies in the dataset**

Year	N
2014-2017	9
2010-2013	8
2006-2009	4

Curriculum development processes in the following countries are part of the dataset: China, Finland, Hong Kong, Hungary, Ireland, Norway, Scotland, Singapore, United Kingdom, The Netherlands and New Zealand. Four studies were of a more general nature.

The authors summarized the studies using a template, which consisted of background information (author(s), date of publication, title); purpose/research questions guiding the study; context of the study (including regulation policies when appropriate); type of study and main conclusions. In addition, to analyze the findings on a more detailed level we used Halinen's (2017) (see her report for OECD2030) four dimensions of time-lag dilemma: a) recognition lag, b) decision-making lag, c) implementation lag and d) impact lag.

The authors used the summaries as primary tool for synthesizing the findings from the studies. When necessary they went back to the original publications.

## 3. Results

### 3.1. Overview of the findings

In this section we provide an overview of the results of the initial analysis of the publications in our dataset. As said above we used Halinen's (2017) four dimensions of time-lag dilemma: a) recognition lag, b) decision-making lag, c) implementation lag and d) impact lag to analyse the selected studies. Halinen (2017, p. 2, adapted) defined these dimensions as follows:

- Recognition lag: how well (future) societal challenges as well as the present state of the education system and the possible obstacles in it are identified.
- Decision-making lag: how curriculum reform planning and decision-making processes are organized in order to reply to (future) societal and present challenges in the curriculum
- Implementation lag: how quickly and how well new goals and procedures are adopted in practice of education and the factors that inhibit/fosters implementation
- Impact lag: how quickly and how well the results of the reform serve the purpose of the reform and the needs of society, in particular when the results of the reform can be identified in the education system and especially in learning results.

**Table 3.1. Overview of studies in the dataset related to the four dimensions of time lag**

Time lag	N
Recognition lag	11
Decision making lag	13
Implementation lag	13
Impact lag	5

This table shows that most of the studies in our dataset discuss issues related to decision-making (13 studies) and implementation (13 studies). Eleven studies describe issues related to the need to recognize change. Only five studies in our data set elaborate on the impact lag.

## 3.2. Recognition lag

The recognition lag deals with time needed to identifying (future) societal challenges as well as the present state of the education system and the possible obstacles in it. Three key issues were identified related to the recognition lag: identification of a need; delays because of lack of agreement and factors fostering adoption of the need for change.

### 3.2.1. *Creating awareness: Identifying the need for curriculum reform*<sup>1</sup>

The recognition of the need for curriculum reform (either at the system level or at the subject domain level) was addressed in several studies in our dataset. Most studies refer to a need for curriculum renewal, because of changes in society. The time needed for identifying and acting upon the recognition of change was not always clear.

Bolstad and Gilbert (2012) (ID17) for instance, when discussing the need for a reform of the curriculum of New Zealand point to social, economic and technological changes taking place in society. They argue that all citizens need to develop competencies that enable them to contribute to the wicked problems of the 21st century. The different meaning of knowledge as well as what we know from the learning sciences on how people learn are, according to them, an important input for rethinking what needs to be

<sup>1</sup> The terms curriculum development, curriculum reform, curriculum renewal and curriculum change are used interchangeably in this review.

taught in the curriculum. The council of primary schools, a major stakeholder in the education arena in the Netherlands, acknowledges that the digital economy will strongly impact the life and work of children that are now in primary school (Kirschner, 2017 (ID01)). The challenge for today's schools is to prepare them as good as possible for this situation. McAra, Broadley and McLaughlin (2013) (ID26) when reflecting on the Curriculum for Excellence in Scotland argue that children are entitled to get education that prepares them for full citizenship. In addition to the social and global changes mentioned above, nation building is an important reason underlying the curriculum reform of the late 1990s in China (Law, 2014) (ID15). The Curriculum Development Council of Hong Kong (2015) (ID13) advocates ongoing curriculum renewal to respond to changes in society in a timely manner. In China the curriculum reform starting in the late 1990s (Law, 2014) (ID15) had a two-stage approach. The first stage mainly focused on creating awareness of the need for change and drafting new curriculum standards. Much effort was put in gathering input from a large amount of many different stakeholders to identify the needs that had to be addressed in the new curriculum. This part lasted about four years, mainly because of the extensive data collection.

Several studies refer to the need to change subject curricula in order to keep them relevant and up to date. Changh (2011) (ID18) describes the need to update the geography curriculum in Singapore, because students do not see the relevance of the current curriculum for their lives. The expectations society has about the potential of engineers to help solve sustainable development challenges prompted engineering education programs in higher education to review the curriculum (Desha, Hargraves & Smith, 2009) (ID24).

Dissatisfaction among scientists, interest groups and industry with the level of Information and Communication Technology in the curriculum in England has led to the implementation of Computing as a new subject that aims to get students interested in further studies in Information and Communication Technology as well as serve all students in becoming digital literate (Brown, Sentence, Crick & Humphreys, 2014) (27).

### ***3.2.2. Disputing the need for change***

The need for curriculum renewal is recognized in many jurisdictions. However, important stakeholders, such as teachers, may dispute the need for change. Two studies in our dataset report such lack of agreement delaying the renewal process.

In the Netherlands a variety of stakeholders (students, parents, teachers, school boards, industry etc.) engaged in a national dialogue about important elements of future-oriented education. Initially many welcomed the proposals resulting from the dialogue. However, it turned out that short before the parliamentary debate about the proposals was to take place teacher interest groups and teacher unions did not agree with the recommendations and questioned the process. The underlying discussion was about ownership: do educational professionals (teachers in particular) own the curriculum or society as a whole (Van Schaik, Nieveen & Voogt, 2017) (ID21). As a result, the renewal process was delayed with at least one year. Also in Ireland (King, 2017 (ID02) political unrest and the feelings of teachers not being consulted about important changes in the lower secondary education curriculum made that teacher unions did not support the proposed changes. As a result, the new curriculum framework had to be re-written, causing delay in the process.

### 3.2.3. *Fostering awareness of curriculum reform*

Factors fostering the awareness of the need to change the curriculum may accelerate the process. We found three factors in our data set: concerted lobbying, shared key principles guiding the change and leadership that fostered the awareness process.

Brown et al. (2014) (ID27) showed that concerted lobbying from industry and interest groups as well as from computer science teachers helped the government in England to realize that there was a problem with the position of information and communication technology in the curriculum. In particular the argument that computer science would be beneficial for all students helped the government to adopt the idea that a new subject in the curriculum was needed. The buy-in from the government resulted in a quick uptake of the problem and a relatively fast process of about five years from awareness to implementation.

To create awareness of the need for future-oriented teaching and learning in New Zealand, Bolstad and Gilbert (2012) (ID13) recommended three key ideas: diversity, connectedness and coherence. These key ideas serve as principles underlying the reform and help to structure the discourse and the policy response. In Scotland such principles were the result of a national debate leading to the Curriculum for Excellence (McAra et al., 2013) (ID26). At subject level lack of relevance of the earlier curriculum triggered the need to change the geography curriculum in Singapore (Changh, 2011) (ID18). A concrete project of the Geographical Association showing how the curriculum can be changed in a future-oriented curriculum that engages students in investigating change processes at the local and global level, served as a concrete example of the change needed and enabled the awareness for the change.

Barber, Chijioke and Mourshed (2010) (ID23) studied 20 educational systems from different parts of the world that started a reform to improve student outcomes. They found that major reasons to start a reform are shared feelings of urgency (a socio-economic crisis, a highly regarded analysis of the current performance of the system) and a change in leadership. New strategic and political leaders do not cause the change, but they are granted the trust to take the lead and make use of the opportunities provided to them to initiate the change process. Yek and Penney (2006) (ID19) studied technical education in Singapore also observed that leaders with a clear vision on education are important in the awareness process. Leadership, together with sufficient funding, can contribute to the trust necessary for the process to be successful. Law, 2014 (ID15) shows that for creating awareness, it is important to engage stakeholders at an early stage. That's why the curriculum reform of the late 1990s in China not only adopted a top-down approach to the reform but involved important curriculum stakeholders from the early start.

### 3.3. Decision-making lag

The decision-making lag refers to the time needed to the organization of planning and decision-making processes in order to reply to (future) societal and present challenges in the curriculum. Several studies in our dataset report key issues in decision-making processes guiding curriculum reform that affect the time needed for the process. These key issues are reported in the following sections.

### *3.3.1. Ad hoc or ongoing curriculum renewal*

Several jurisdictions<sup>2</sup>, e.g. Finland and Norway, have adopted an ongoing approach to curriculum renewal, in which the curriculum is periodically updated. In Finland for instance the curriculum is renewed approximately every ten years (Pietarinen, Pyhälto & Soini, 2017 (ID11)). Also in Norway the curriculum changes about every ten years (Siveskind & Westbury, 2016) (ID20). To be able to focus, deepen and sustain the reform started in 2001, the Curriculum Development Council (2015) (ID13) in Hong Kong advocates for a process of ongoing curriculum renewal to be able to cope with changes in a dynamically changing society and relate those to the results already attained.

Contrary, curriculum renewal in Hungary for instance is characterized by ad hoc reforms due to changes in government Horvát, Kaposi & Varga, 2013 (ID28). Also The Netherlands (SLO, 2008) (ID05) and Ireland (NCCA, 2017) (ID12) are examples of countries in which (parts of) the curriculum is renewed ad hoc, often because of concerns in society about its quality (SLO, 2008) (ID05). Only recently the Netherlands started a process to review the specifications of the primary and secondary curriculum because of altering expectations for education in a rapidly changing society (Van Schaik et al., 2017) (ID2017). The intention of this process is to initiate a periodic review of the curriculum in the future.

In a white paper the National Council for Curriculum and Assessment in Ireland (NCCA, 2017) (ID2017) argues that ongoing periodic curriculum renewal, such as taking place in Finland and Norway, may be more efficient in terms of the time, because relative smaller are needed to keep the curriculum up to date. In addition an ongoing periodic process may also avoid the perception of key stakeholders that updating the curriculum always implies large-scale reform. A disadvantage might be that society shifts its problems to education (see also Voogt, Nieveen & Klöpping, 2017) resulting in a ‘claim on aims’. However, the NCCA (2017) also realizes that a periodic approach to curriculum renewal would require more resources and staff to manage the process.

### *3.3.2. Stages in curriculum renewal processes*

The National Council for Curriculum and Assessment in Ireland (NCCA, 2017) (ID12) analysed curriculum development processes in several countries (Scotland, Ireland, the Netherlands and Australia) and reported that such processes usually have the following major stages: analysis and planning, development, piloting and monitoring/evaluation. These stages reflect the so-called ADDIE model (Analysis, Design, development, Implementation and Evaluation (Gustafson, 2002), a systematic approach to curriculum renewal. According to the NCCA (2017) such an approach ensures “that curriculum specifications are of a high quality, are well-researched, are theoretically and educationally sound, are up-to-date with developments internationally, are fit-for-purpose and well-grounded, and have a level of buy-in by those involved in the education system prior to their implementation” (p. 25). They acknowledge that such a process takes time, because of the research needed to do a good job and the involvement of stakeholders to create ownership. In the countries studied by the NCCA the time needed to complete the process was between two and four years prior to implementation. In Norway the development of the L97 curriculum took about three years (Siveskind & Westbury, 2016) (ID20) from the moment the parliament had agreed on the rationale of and focus for the

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<sup>2</sup> It is to be expected that the analysis of the policy questionnaire will provide more detailed insights in the frequency of the curriculum renewal processes in jurisdictions.



change to its formal adoption. After formal adoption of the new curriculum, the time to implement it should not be underestimated (see also implementation lag). However, the development of reference levels for numeracy and literacy in the Netherlands (SLO, 2008) took only about one year, also because policy and society felt the urgency to improve the performance levels in these domains.

According to NCCA (2017), curriculum renewal processes may be more efficient – in terms of time – when development and implementation processes are not taking place consecutively, but are intertwined. In China’s curriculum reform process, further development of the draft standards and implementation were intertwined in the fine-tuning (second) stage (Law, 2014) (ID15). The draft curriculum standards were piloted in close collaboration with schools. Followed by a process in which schools implemented the standards on an experimental basis. During the process the standards were further refined. This stage took about ten years and resulted in a final version of the standards in 2011. Compulsory implementation started in 2012.

### *3.3.3. Steering of curriculum renewal processes*

The stages of curriculum renewal processes described above roughly describe the curriculum renewal processes taking place in many educational systems. However, according to Barber et al. (2010) (ID23) there is a substantial variation between educational systems in how the processes are organized and decision-making takes place. The curriculum reform process in Finland for instance is led by professionals of the Finnish National Board of Education (Pietarinen et al., 2017) and not by politicians. Also in Ireland and Australia the state agency responsible for curriculum takes the lead (NCCA, 2017). In the curriculum reform process in Norway (L97) the influence of the Ministry of Education was large during all stages of the process, despite the involvement of a variety of professional stakeholders in the actual curriculum development work (Siveskind & Westbury, 2016). Also in China, the Ministry of Education had a core role during the whole process (Law, 2014). In the Netherlands the Ministry and parliament had a role in approving the products of and plans for main stages in the process, but a variety of professionals are responsible for the process itself (Van Schaik et al., 2017). The political sensitive character of the process in the Netherlands was time-consuming. Waslander, Hooge and Theisens (2017) (ID04) describe a dominant role of the government in the way education in the Netherlands is steered, often through the use of existing or newly created organizations and networks. They argue that there is a need to make the system less political.

### *3.3.4. Engaging stakeholders*

It is generally acknowledged that involving stakeholders in the curriculum renewal process is crucial for its success (Changh, 2011; Law, 2014; NCCA, 2017; Pietarinen et al., 2017; Siveskind & Westbury, 2016, Van Schaik et al. 2017). A buy-in from a variety of stakeholders may pay off and result in a better and smoother implementation of the new curriculum.

In Finland many different stakeholders (schools, universities parents’ associations) are formally invited to participate in the process, while everyone is encouraged to comment on drafts published on the Internet (Pietarinen et al. 2017). In the curriculum reform process in China (Law, 2014) (ID15) much effort was put in involving stakeholders. During the first stage (eight years), which was aimed at defining the need for change, opinions from major stakeholders (students, school principals and members of education

committees) were sought through large-scale surveys. After that feedback about draft curriculum standards were solicited in public seminars. During the fine-tuning stage (ten years) schools piloted the standards and feedback was asked. In the curriculum reform process in Norway (L97) a variety of stakeholders collaborated in curriculum committees at the subject level and at the core curriculum level (Siveskind & Westbury, 2016). In addition representatives from the Ministry, schools, intermediate organizations, regional and university colleges and diverse interest groups were involved in the process. Changh (2011) mentioned that in the process of the renewal of the geography curriculum in Singapore many different stakeholders (teachers, curriculum developers, university professors, teacher educators) were involved. In addition the plan is to create network of geography teachers that can further advance curriculum renewal during implementation. In the Netherlands the evaluation of the national dialogue aimed at developing a shared vision on the curriculum in rapidly changing times showed the importance of having key stakeholders (teachers in particular) involved (Van Schaik et al., 2017). In the next phase of this process teachers will become actively involved in contributing to shaping curriculum specifications.

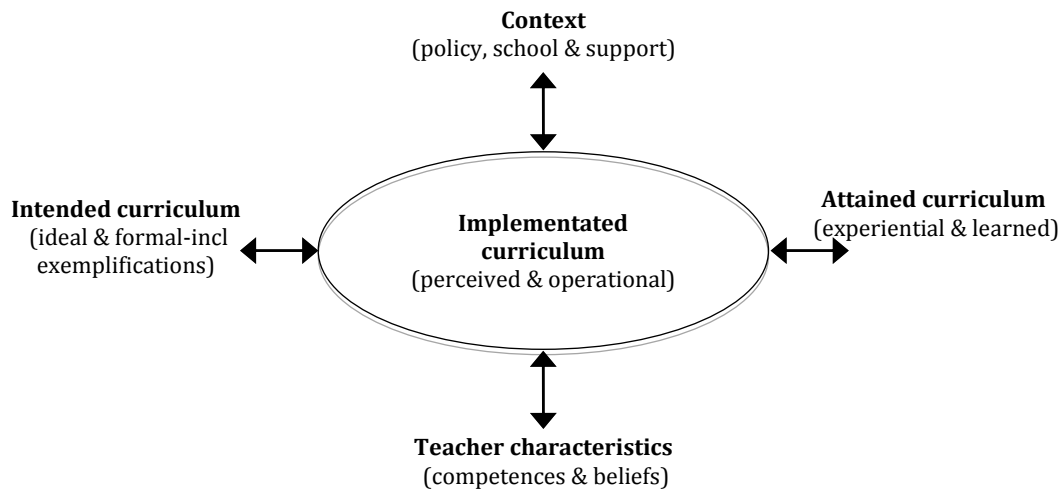
### *3.3.5. Decentralized curriculum development*

The white paper of the NCCA (2017) mentions the possibility to keep the curriculum up to date, when there is room at the local and school level for curriculum renewal. This assumes that national curriculum specifications allow for decentralized curriculum planning and decision-making. Decentralized curriculum development requires that national curriculum specifications offer room to adapt and decide about the curriculum at the local and school level. According to the NCCA (2017) teachers and schools are not always ready to decide themselves about curriculum matters. For instance in the Netherlands national curriculum specifications are of a broad nature; they offer much autonomy to teachers and schools to decide about the school curriculum. However teachers traditionally use textbooks and they do not feel the autonomy granted to them (Voogt, Nieveen & Klöpping, 2017). Hence teachers and schools often need support when they - to some extent - become responsible for (parts of) the curriculum and this might take time. Kirschner (2017) argues that the priorities of schools in implementing so called 21st century skills might differ. He suggests that some schools need to put their priorities on literacy and numeracy first. The implementation of local curriculum planning and decision-making seems also difficult when schools and teachers have to prepare their students for high-stakes tests (NCCA, 2017; Voogt, Nieveen & Klöpping, 2017). Policy makers also understand decentralized curriculum planning and decision-making in different ways. Mølsted (2015) compared decentralized curriculum policy in Norway and Finland. She found that in Norway the policy can be characterized as ‘management of expectations’, implying that schools and teachers have room to adapt the curriculum locally, but in the end are expected to deliver the national curriculum. In Finland, the policy was characterized as ‘management of placement’, indicating that teachers and schools are granted responsibilities to adapt the curriculum to the local context.

## **3.4. Implementation lag**

The implementation lag refers to how quickly and how well new goals and procedures are adopted in practice of education and the factors that inhibit/foster implementation. From the literature that was considered for this study, it becomes clear that several issues arise during the implementation stage that again causes time lag for a curriculum renewal.

**Figure 3.1. Key relationships in curriculum change model**



To categorize these issues, we made use of a model (see Figure 1) by Nieveen, Sluijsmans and van den Akker (2014). They define the “implemented curriculum” as what an innovation consists of in practice, the curriculum-in-action. Many factors and actors influence and are influenced by the way teachers enact a curriculum change. The extent to which students will notice the change and show different learning results (which is of course the main aim of any curriculum renewal) is heavily influenced by the perceptions of teachers and the way they put the change into practice.

The horizontal line in the model represents three forms of a curriculum: the intended, the implemented, and the attained. Building on the work by John Goodlad (1979; see also den Akker, 2003) these three forms can be split up in the following six representations of the curriculum, which is especially useful in the analysis of processes and outcomes of curriculum innovations (see Table 4).

**Figure 3.2. Representations of a curriculum**

<b>INTENDED</b>	
Ideal	Basic vision, philosophy or dreams underlying a curriculum
Formal/written	Intentions as specified in curriculum documents and exemplifications
<b>IMPLEMENTED</b>	
Perceived	Curriculum as interpreted by its users, especially teachers)
Operational	Actual process of teaching and learning
<b>ATTAINED</b>	
Experiential	Learning experiences as perceived by learners
Learned	Resulting learning outcomes of learners

The vertical line in the model represents the non-curricular factors that will influence the implemented curriculum: the characteristics of the teachers and the (school) context within which they act. With respect to teachers’ characteristics, many scholars point at the fact that curriculum change calls for changes in teaching competences and in teachers’

beliefs. The context of change consists of colleagues, school leadership, parents and their stance towards national and local educational policies. The context also includes the availability of a supportive school culture with financial resources, time, and internal and external support (including pre- and in-service teacher education, media and lobby groups).

The literature included in this review discusses several of these issues inhibiting implementation of the renewal and causing for time lag. These issues were categorized using the four main components on the horizontal and vertical line in Figure 1.

### *3.4.1. Issues on the horizontal line: the intended and attained curriculum*

The intended curriculum of a country or region provides insight in the basic philosophy underlying a curriculum and includes the specifications of these intentions. The enactment of curriculum policy in schools needs both an interpretation of the policy texts and their translations into practice. The intended curriculum itself and/or the way the exemplifications are communicated with schools and teachers may hamper or slow down the implementation process. In the literature we found the following aspects:

- Steering overload

In the Netherlands, every educational policy theme has its own steering dynamic, with steering committees, networks of stakeholders, publishers, test developers etc. For Dutch school this means that they have to deal with numerous groups and networks, policy documents and exemplifications for each and every curriculum theme. Schools are overwhelmed with this overload of steering (Waslander et al. 2017) (ID04).

- Reduced perspective on learning

For the context of Singapore, Tan (2006) (ID16) states that the fixation on reducing learning to a set of skills measurable through the national examinations is part of the exam-culture. This hampers the introduction of creative thinking and critical inquiry. Nevertheless, the Ministry of Education of Singapore encourages the schools to "teach less and learn more", by providing time to reflect by hiring more teachers, by reducing the content in the curriculum and by setting aside timetabled time for teachers to engage in professional planning, reflection and sharing.

- Lack of guidance materials

In Hong Kong, the Curriculum Development Council (2015) [ID13] provides several strategies to improve the ongoing curriculum renewal of the school curriculum, among these they stress the importance of providing schools with better and flexible cross-curricular linkages. Also in Norway (Mølsted, 2015) (ID22), the Norwegian Directorate developed guidance materials because teachers expressed a need for these. The documents provide the government's interpretations of the curriculum regulations to teachers. Also in Scotland and the Netherlands schools and teachers were provided with guidance materials (McAra et al., 2013; SLO, 2008). Other countries, like Finland, chose not to provide more exemplification to teachers, but rather allow Finnish teachers to further develop the national curriculum towards local curriculum interpretations that teachers in schools will use when preparing their lessons (Mølsted, 2015).

- Lack of alignment between responsibilities and performance

The centralization or decentralization of curriculum interpretations is an important issue to consider. In their McKinsey report, Barber et al. (2010) indicate that schooling systems

in poor and fair performance achieve improvement through a centre that scripts instructional practice for schools and teachers. However, they warn that such an approach does not work for systems with good and great performance. These systems achieve improvement by increasing the responsibilities of schools and teachers to shape Instructional practice.

- Student resistance

The attained curriculum includes all learning experiences as perceived by learners and the resulting learning outcomes of learners. The attained curriculum may have its back drop on teachers, when it comes to curriculum change. Students may become resistant to change and 'just ask for the notes', instead of engaging in deep learning. For instance, in the case of Singapore (Tan, 2006), students themselves are reported to be exam-oriented and oftentimes lack a desire for learning and are too busy to reflect. Teachers adjust their teaching to this culture.

### *3.4.2. Issues on the vertical line: teacher characteristics and (school) context*

- Complexity of teacher change

When it comes to teacher characteristics and competences, authors put several issues to the foreground that link to the need for teacher change in case of a curriculum renewal. These issues take time to resolve. According to King (2017) [ID02], one needs to acknowledge that teachers' attention to reform is complex, especially when the reform proposes to change the teaching practice. For instance, the renewal in Hongkong to further enhance Learning to Learn implies (Curriculum Development Council (2015)[ID13] improvement of teachers' repertoire of pedagogy to promote student-centered learning and teaching, e-learning and self-directed learning; promoting assessment literacy to inform and improve the effectiveness of learning; catering for and embracing learner diversity, especially in the areas of special educational needs, gifted education and education for non-Chinese speaking students. Most of these aspects take time for learning.

Kirschner (2017) [ID01] argues that schools are not ready to take up changes to make learning future oriented. According to him, schools are too slow when it comes to incorporating changes in future jobs into their curriculum, partly because teachers lack knowledge on future jobs and because they do not have the right competences (such as computational skills) to assist students in their preparation for the future.

- Need for teachers to challenge values and culture of a country

The renewal may also challenge the values and culture of a country or region. For instance, in Singapore, the renewal focuses on a need for students to ask questions. However, according to Tan (2016) [ID16], Asian values, especially Confucian teaching, do not endorse and individual's right to question and challenge what is being taught. Guidelines as to what constitutes acceptable questioning need to be in place. Changing a value system certainly takes time.

- Need for contextualized policy responses

According to King, there is a need for bringing about a shared meaning of the purpose of the change between the system and schools and therefore, there is a need for contextualized policy responses, acknowledging the uniqueness of schools. Similarly, The Curriculum Development Council (2015) of Hong Kong [ID06] stresses that to implement the ongoing renewal of the school curriculum, schools need to be encouraged

to consider their school contexts. Moreover, it states that every stakeholder plays a part in the ongoing renewal of the school curriculum and meetings, school visits and focus group interviews will need to be conducted for reviewing implementation and collecting feedback from a wide range of stakeholders to improve the support strategies.

- Need for time and resources

On top of that, changing the routines in a school is complex and requires time, attention and resources (Waslander et al., 2017) (ID04). Tan (2016) (ID16) explains for the Singaporean situation, that due to time constraints it is difficult for teachers to become resource persons for their students. They need to time to read widely, reflect and adapt and design appropriate pedagogies to promote critical thinking in their students.

- Need for professional development

Curriculum renewal usually requires professional development of teachers and schools. This implies that time is needed to provide professional development opportunities for teachers and school leaders (NCCA, 2017, SLO, 2008). Also initial teacher education institutes need time to prepare new teachers for the reform (NCCA, 2017; SLO, 2008). The provision of professional development opportunities for implementation is particularly relevant and time-consuming for the implementation of new subject areas (e.g. computing) (NCCA, 2017; Brown et al., 2014). In some instances, for example when it comes to curriculum renewal towards engineering education for sustainable development, Desha et al. (2009) [ID24] rightfully point at the fact that capacity building is needed over time and on many levels, requiring a process of curriculum renewal across all levels (undergraduate education, postgraduate education, PhD research and professional development for practicing engineers and educators). In the case of Hong Kong (Curriculum Development Council (2015) (ID13), the renewal required follow-up support for schools to build up the professional capacity of school leaders, middle managers and teachers in understanding the ongoing renewal and facilitating effective implementation. Here and in many other countries the support measures include professional development programmes, professional sharing opportunities, school-based professional support, learning and teaching resources.

- Need for leadership continuity

In the end, it is up to the school leadership and teachers to answer the question 'How far and how fast are we willing and able to proceed to make the transition?' (ID06)(Unesco, 2010). Leadership continuity is essential in improving systems. This refers to the longevity, time that strategic leaders are in charge should be not too short, i.e. seven years, and to the active cultivation of the next generation of leaders, ensuring a longer-term continuity in reform goals.

### 3.5. Impact lag

Impact lag refers to how quickly and how well the results of the reform serve the purpose of the reform and the needs of society, when the results of the reform can be identified in the education system and especially in the learning results. Impact lag brings us back to the underlying question of this literature review: why do changes in education fall behind the changes taking place in the real world. The time needed until students will get involved in learning experiences that result in the intended learning outcomes depends to a great deal on the complexity of the change (see previous sections) and the schooling time span of the renewal. In five contributions the issue of impact lag was discussed.

### ***3.5.1. Substantial change of the curriculum***

In their final report (SLO, 2008) [ID05] the Dutch expertise group on learning strands for numeracy and literacy provided the formula for calculating the impact lag as follows: "the curriculum time span + one year". Because the span of their renewal covered basic education (students of 4-16 years), the time lag would be 12 plus 1 is 13 years. Meaning that learners in year 1 who experience the renewal will leave the renewal after 12 years. They will be the first students who have been entirely in the new system.

However, Desha et al. (2009) [ID24] calculated that the timeline usually covers 15-20 years (based on three to four program accreditation cycles) when changing the engineering curriculum in higher education that meet changing industry and accreditation requirements. On top of the average pathway to achieving engineering graduate status (from enrolment to graduation) is three-five years. In addition, there is a period of five-ten years for graduates before they can effect change as professional engineers. That is why they advocate forward planning and strategic thinking about the transition to renewal by educational departments.

### ***3.5.2. Improvement of performance in the current system***

The McKinsey report by Barber et al. (2010) [ID23] is more optimistic when it comes to improved numeracy and literacy levels of students. They found that gains can be achieved in six years or less. For instance, according to their study students in India, Brazil and South Africa have significantly improved their numeracy and literacy levels within just two-four years.

### ***3.5.3. Curriculum renewal: Examples of fast tracking***

Our dataset contains three studies of relative fast decision-making in curriculum renewal processes. Two studies are in the domain of Computing (Brown et al., 2014; NCCA, 2017) and one study is in higher education engineering (Desha et al., 2009).

Brown describes that the decision-making process about Computing in the UK was relatively fast, because the lobby for a new subject Computing was effective and timely. The government was positive towards Computing as a new subject (see also recognition lag) and the national curriculum was just under review, which offered concrete possibilities to realize the change. In Ireland Computer Science as a new subject in upper secondary education is currently in a fast track decision-making process. The process started mid-2016 and decisions are expected by the end of 2017. This was possible, according to NCCA, because of the (international) consensus on the content of the subject and its alignment with current curriculum and assessment arrangements in upper secondary education (NCCA, 2017). Desha et al. (2009) describe possibilities how curriculum reform processes in engineering programs in higher education can be shortened. According to them education departments need to be in control and not only react upon developments in economy and society. Essential is forward planning, which implies that trialing of new content in exemplary courses, using the experiences of the trials to develop other courses and staff development take place as much as possible simultaneously instead of consecutively.

## 4. Conclusions

The aim of this review was to identify elements in curriculum planning and enactment that contribute to time lag. In addition we wanted to know how time lag is handled in curriculum renewal processes. We found very few publications that explicitly dealt with time lag in curriculum reform. For this reason we also searched for studies that describe curriculum development processes in jurisdictions that are in the process of curriculum renewal because of the rapid changes taking place in our current society. In this way we expected to find elements of the curriculum development process that requires time. In this way we intend to contribute to a better conceptualization of time lag.

We used Halinen's (2017) four dimensions of the time-lag dilemma to analyze the studies in our dataset. These dimensions align well with Barnard's conceptualization of time lag (Barnard, 2003) (ID07). He identified time lag between the need for action and decision and between decision and execution, resulting in three stages: "1) delay in recognizing the need for decision; 2) time required in making it and 3) time necessary for promulgating and inculcating it" (p.33). Barnard (2003) argues that processes such as curriculum renewal processes, because of their democratic character, are inherently slow. In the next sections we summarize our findings and point to aspects of the process that require time.

### 4.1. Recognition of the need for change

The time needed to recognize the need for curriculum change is referred to as the recognition lag. Based on our findings it is difficult to estimate the time needed for raising awareness that change is needed. Often a variety of stakeholders participate in the process that aims to create awareness for change among policy makers, the education community and the society at large. We found that in particular teachers need to be actively involved from the early stage too prevent delays in the process. Factors that foster the awareness process are: concerted lobbying, widely supported key principles underlying the intended change, and leadership.

### 4.2. Planning and decision-making

The time needed for the organization of planning and decision-making processes is referred to as the decision-making lag. Countries have different traditions in how they organize decision-making in curriculum change processes. Ad hoc approaches to curriculum renewal seem more politically driven and time-consuming than ongoing curriculum renewal processes and seem more vulnerable to resistance to change from schools and teachers as they experience the reform as a major change. Ongoing curriculum renewal may need more permanent staff and resources at the ministry or in state curriculum agencies to organize the process. In curriculum renewal processes the following stages are usually distinguished: analysis/ planning, development/ piloting and monitoring/evaluation after full implementation. How these processes are organized may differ, but they usually take at least 2-4 years prior to full implementation. Important for the success of the process, but also time-consuming is the need to engage stakeholders during all stages in the process. For this reason some argue that the process may be more efficient when development and implementation are more intertwined. In this way schools and teachers become a more active part of the development process and is the



development of the new curriculum not left to curriculum committees alone. Also decentralized curriculum development at the local or school level is seen as an opportunity to quickly respond to changes in society. However, it is generally acknowledged that teachers and schools need to be ready to take such responsibilities and often need support in curriculum development matters.

### 4.3. Adoption and implementation

The time needed to adopt and implement the new curriculum in educational practice is referred to as the implementation lag. The implementation of a new curriculum has two dimensions. The first dimension is related to the discrepancies between the intended and attained curriculum. We found several aspects that contribute to creating discrepancies between intentions and attainments. A reduced perspective on the curriculum's intentions may occur when complex skills are translated in a set of measurable skills. Also, students might not be interested in the full intentions of the curriculum as they often are exam-oriented. Teachers need guidance and exemplification of the new curriculum, when these materials are lacking implementation may lag behind. However, too much steering may also result in feelings of overload (cf. Voogt, Nieveen & Klöpping, 2017). Finally, also the way supported is offered needs to fit with the educational system. The second dimension concerns to the non-curricular factors that influence teachers' perceptions about the new curriculum. This dimension acknowledges that change is often complex. Change requires teachers to change, not only in using new materials and developing new repertoires. Substantial change also challenges teachers' values regarding education, sometimes as deep as cultural values. For this reason, it is important to take time to develop a shared meaning of the change and offer resources and professional development opportunities to teachers and schools to make sense of the reform in the local context. Finally, continuity in leadership helps the implementation of the change.

### 4.4. Identifying impact of the change

The time needed to identify the impact of the reform in the educational system is referred to as impact lag. By reflecting on the process as a whole (recognition, decision-making and implementation) we identified the complexity and time-consuming aspects of the change process, despite the differences across countries in the way curriculum renewal processes are taking place. Impact lag brings us back to the underlying question "why do changes in education fall behind the changes taking place in the real world". As we found in our review, the time needed for substantial renewal of the curriculum usually takes more than ten years. Less time is needed when systems aim to improve the performance of the current system, which was the case in the McKinsey study (Barber et al., 2010); they found a time span of six years or less. Our review concludes with few examples of fast tracking curriculum renewal processes for subject domains and programs that are considered of high importance from a societal and economic perspective.

Finally, our review analysed existing practices of curriculum renewal processes at the state level. Williamson (2013) in his study about "The future of the curriculum. School knowledge in the digital age", poses a more fundamental question about the future of curriculum. According to Williamson (2013) "the future of education and learning is decentered, distributed, and dispersed rather than narrowly centered, channeled, and canalized" (p.7). He argues that in the digital age not only teachers and students need to change as a consequence of the outcomes of curriculum renewal, but that the curriculum renewal process itself needs to change as well. He foresees that the state will no longer be

the central authority in curriculum renewal processes. In his view fluid networks of individuals (designers, software developers, scientists, teachers, students and parents), organizations (within and outside schools) and sources of expertise (of a multidisciplinary nature) will develop prototypical curricula, which will be used and adapted to local contexts, but are at the same time part of a globalized educational reform network. In case studies from the US, The UK and Australia this approach to curriculum renewal is illustrated. In such an approach the issue of time lag may be much less of an issue, because the change occurs more evolutionary and those who create and implement the change are involved from the start.

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## *Technology in Education: Effects, affordances and conditions for effective implementation- A review of recent literature*

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### **1. Introduction**

This literature review is part of the Curriculum Analysis of the Future of Education and Skills: the OECD Education 2030 project. The major purpose of the OECD Education 2030 project is “to develop a common language and shared space within which countries could both individually and collectively, explore issues around the design of instructional systems” (EDU/EDPC (2016)6, p.2).

In the frame of this study, a literature review study has been conducted to find out about the potential and impact of technology to change curriculum practice. The review will outline the potential use of technology to realize curriculum practices, considering the following dimensions of the curriculum analysis in the OECD Education 2030 project: curriculum quality, equity and equal opportunities for learning, and effective implementation. This paper will focus on what research tells us about the impact of technology on curriculum practices and the factors that inhibit or foster successful implementation of technology.

The overall research question for the review is:

*What is the impact of technology in realizing curriculum quality and equity and equal opportunities for learning, and what is needed to effectively implement technology to realize this impact?*

## 2. Method

### 2.1. Search strategy and analysis

To search for relevant literature combinations of the following four groups of terms were used:

1. Technology (technology, information technology, information and communication technology, ICT, computer-assisted instruction, technology enhanced learning, technology access)
2. Curriculum & Instruction (curriculum, cross-curriculum, curriculum integration, instruction, teaching, learning, adaptive learning; personalized learning; formal learning, informal learning, distance learning, virtual schools)
3. Equity (access; rural schools, special needs, gifted students, low social economic background, gender) and
4. K-12 education (the search will be limited to primary and secondary education)

These terms have been further elaborated and refined using descriptors provided by the ERIC thesaurus. The search has been conducted in major databases Web of Science, PsychINFO and Eric. The snowball method has been used to find studies would help to that meet our research goal. The exact search terms are provided in Appendix 1.

For the initial selection the retrieved studies also had to meet the following criteria:

- Published after 2005
- Articles written in the English language
- Peer-reviewed journal articles, dissertations and conference contributions accessible by the research team
- Empirical studies of adequate quality (we prefer quantitative studies, however peer-reviewed qualitative studies are also welcomed)

The initial database consisted of 638 studies. In a first round of selection, abstracts were screened. Articles that were not relevant to the research aims, with sample size < 10 or conference papers were excluded from the study. Articles that were questioned to be relevant for the research aims, with relatively small samples (< 30) and dissertations were considered for 'doubt'. These studies could be reconsidered when there was a need for more studies in later stages of the selection.

All studies that seemed relevant to the research aims, with appropriate methods (larger samples for quantitative studies, relatively large samples for qualitative studies) were considered for use in the study. After this selection round, 140 studies were selected for closer inspection. In the next round, the full articles were attempted to access. However, a substantial proportion appeared inaccessible to the researchers, and were therefore dropped. Furthermore, studies that were published before 2010 were excluded. Only particular studies that appeared relevant, and were published before 2010 were retained. After this selection, 72 studies remained eligible for use.

An overview of the study characteristics (year of publication, jurisdiction, methods, research questions, conclusions, and implications) was developed. The relevance of each of the articles was compared to determine which studies were most suitable for further review. In this phase we selected studies that were conducted in real classrooms (no

laboratory studies) from a wide range of jurisdictions. We discussed decisions in the research team until agreement was reached. This resulted in 27 studies that were included in the dataset. During the analysis three studies were deleted, because they did not fit the research aims, and two studies were added. The final dataset thus contained 26 studies.

These studies were read and summarized in an excel file and a word template. The summary describes: background information (author(s), date of publication, title, jurisdiction); research question(s) and purpose of the study; research design; general conclusions and specific conclusions about the three key policy factors: quality of curriculum, equity and opportunities for learning and planning effective implementation. One member of the research team used these summaries as primary tool for analyzing and synthesizing the findings from the studies. When necessary the researcher went back to the original publication.

## 2.2. Overview of the dataset

The studies in the dataset come from 13 different countries (the two meta-analysis not included). Twelve studies are from the USA. One study is from each of the following countries: Malaysia, New Zealand, Pakistan, Canada, Kenya, India, Israel, Australia, Netherlands, China, Turkey and Korea.

The distribution of the studies in our sample according to the applied research method is presented in Table 2.1.

**Table 2.1. Distribution of studies in the sample according to applied research method**

	# studies	Min no. of students	Max no. of students
Experiment	10	37	16143
Survey	3	277	955
Qualitative	1	720	720
Mixed methods	8	28	1129
Meta-analysis	2	36793	660553
Randomized Control Trial	2	3494	6304

The studies in the dataset are about equally distributed between elementary and secondary education. Seven studies are conducted in both elementary and secondary education (table 2.2).

**Table 2.2. Distribution of studies in the dataset according to educational sector**

Educational sector	Number of studies
Elementary education	9
Secondary education	10
Elementary + Secondary education	7

### 3. Results

In this section, it will first present an overview of the findings of this study, follow by reporting about the contributions of technology interventions to student learning. It will then discuss the affordances of the technology that contribute to these effects and the conditions that need to be in place to realize the effects.

#### 3.1. Overview of findings

19 studies reported on effects of a technology-rich intervention on student learning for a specific content domain. See table 3 for an overview. 7 studies focused on aspects of literacy, writing and reading in particular. 8 studies reported about technology-rich interventions in mathematics education. 7 studies focused on the effects on student learning of technology interventions in other content domains (modern foreign languages and science) and skills (problem solving, creativity and self-regulation).

**Table 3.1. Distribution of the studies in the dataset according to content domain and educational sector**

Content domain	Elementary education	Secondary education
Literacy	8	4
Mathematics	7	4
Other subjects and skills	5	3

*Note:* Some studies were conducted in more than one content domain and educational sector.

The studies in this review describe the effects of a variety of technologies that are aimed to enhance teaching and learning in the curriculum. We organized this diversity of technology applications into the following categories (Voogt & Fisser, 2015; Means, 1994):

- *Tutorials/ drill & practice:* Tutorials are designed to learn new content, and to instruct the learner. Drill and practice software differs from tutorials, because they do not teach something new but focus on memorization of information or on practicing skills that are already acquired elsewhere. Often these applications



provide some form of feedback to students about their learning and they provide information to teachers to be able to monitor students' learning progress.

- *Exploratory environments:* These environments are situated learning environments usually with interactive features. Simulations and games are examples. Simulations are representations of a part of reality and provide learners the opportunity to engage in situations to that will help them to understand complex concepts and/or procedures. Games are virtual worlds, they are usually competitive and rule –based and aim to engage students in challenging assignments.
- *Communication media:* These media are usually Web 2.0 environments that offer possibilities to interact and collaborate with each other, often to create own content.
- *Tools:* The software applications in this category are often not specifically designed for educational purposes of the basic application software of nearly every computer. They may support students in their learning process, because of their capability to structure information, to present information in it in different forms and to generate own content.
- It was noted that in a number of the studies presented in this review report to have focused on a combination of applications. We labeled this as *comprehensive digital environments*.

6 of the studies in our dataset focused on technology applications that we categorized as tutorials and drill and practice applications. 6 studies provided the students with an exploratory environment. Only one study used communication media in the intervention. We did not have any study that solely used tools in the intervention, but tools were often part of the comprehensive digital environments that students were engaged in. Comprehensive digital environments are mostly used when every student has access to a device in the classroom.

**Table 3.2. Use of different types of technology applications used in the studies in the dataset**

Types of technology applications	# studies
Tutorials/ drill & practice	6
Exploratory environments	6
Communication media	1
Tools	-
Comprehensive digital environments	6

The duration of the technology interventions are presented in Table 5. It appeared impossible to make a good estimation of the number of sessions and the time the children used the technology per session, as these numbers were not always reported. Still the duration seemed to vary a lot. For instance Klopp et al. (2014) (ID95) reported three sessions of 12 minutes for elementary and middle school students, who participated in a technology-enhanced science project. In other studies, in particular when students have 1:1 access to technology devices was used daily, but it was not always clear how many minutes (on average) the students used these devices each day and for what purpose.

**Table 3.3. Duration of the technology intervention in the study**

Duration of the intervention	# studies
1 month or less	2
More than one months and less than 3 months	5
More than three months and less than 8 months	5
More than 8 months (about one school year)	5

## 3.2. Curriculum quality: Contributions of technology to student learning

### 3.2.1. Literacy proficiency

7 studies in our sample report on positive effects of technology-enhanced curricula on (aspects) of students' literacy performance. These studies took place in the USA (Wilson, Olinghouse & Andrada (2014) (ID86), Cave & Yekovich (2010) (ID24), Rasinski, Samuels, Hiebert, Petscher & Feller (2011) (ID 252)), New Zealand (Jesson, McNaughton & Wilson, 2015) (ID62)), Israel (Rosen and Manny-Ikan (2011) (ID213)) and Turkey (Kartal & Terziyan, 2016) (ID436)).

#### **Effects of technology applications on student learning in general educational settings**

Cheung and Slavin (2012) (IDX2) conducted a meta-analysis of 84 studies about the effects of technology applications on student performance in reading. Studies included in the study had to last for at least 12 weeks. They found that while computer assisted instruction types of applications did not result in meaningful effect sizes, applications that were better integrated in the curriculum did result in meaningful effect sizes compared to traditional reading methods. Effect sizes were larger for secondary education, for low ability students and for students who are second language learners. Frequency of use of the software applications did not seem to matter.

Wilson, Olinghouse and Andrada (2014) (ID86) studied the effects of automated feedback on the quality of students' writing in 4th-8th grade in the USA (n=995 students). They found that automated feedback improved the quality of students' writing products up to 11- 12th revisions of the writing product (*tutorials/drill & practice*). This effect was independent of grade level or the quality of the first draft of the writing product. However transfer effects of the feedback on new writing tasks were not found. Cave and Yekovich (2010) (ID24) also focused on writing proficiency. They conducted a small-scale experimental study (n=20 students experimental group; n= 17 control group) on the effects of an authentic learning environment (e.g. a Newsroom) fostering writing proficiency in 3rd grade students in the USA. Students were given ample opportunities to conduct meaningful writing activities for real purposes and audiences. Findings showed that the essays of the students in the experimental condition had better quality than control group students (*comprehensive digital environment*).

Jesson, McNaughton and Wilson (2015) (ID62) studied the use of 1:1 netbooks to raise elementary school students' writing and reading proficiency in New Zealand. Every student in the study (n=443 students for data on writing; n=765 for reading) received a netbook and teachers were offered a framework for organizing their teaching, and wireless applications were suggested to use with the netbooks. After the first year of

implementation positive effects of the intervention were found on writing proficiency, but not on reading proficiency. This effect was maintained in 60% of the classrooms after the implementation year. The reasons for the differentiated findings for reading and writing were not clear for the researchers. (*comprehensive digital environment*)

In a large-scale study (5758 students experimental group; 10385 control group) in the USA Rasinski, Samuels, Hiebert, Petscher and Feller (2011) (ID252) studied the effects of specific software to foster reading fluency and comprehension in grade 4-10 students. Students using the software outperformed students who did not use the software. They also showed on average larger gains on a criterion reference reading test compared to the average gains of comparable students in the state/district. (*tutorials/ drill & practice*)

In a small-scale study Kartal and Terziyan (2016) (ID436) studied the development of phonological awareness in 1st grade students in Turkey (n=10 students experimental group; n=10 control group). Phonological awareness skills are considered an important preparatory set of skills for reading. Students in the experimental group used software specifically designed for practicing phonological awareness skills in a meaningful context. They outperformed the control group on letter-knowledge, letter-sound knowledge and phoneme segmentation. (*exploratory environment*)

### **Equity and opportunity to learn literacy with technology applications**

Rosen and Manny-Ikan (2011) (ID215) studied the effects of the ‘Time To Know’ program, a comprehensive digital learning environment encompassing core curriculum subjects. The program uses a 1:1 laptop environment. The study took place in Israel in the 5<sup>th</sup> grade (n=49 experimental group, n=42 control group) and particularly focused on schools with students from a low SES background. The findings showed that the learning gains of the experimental group students on a standardized test in reading comprehension were larger than those of the control group (*comprehensive environment*).

Also Hall, Cohen, Vue and Ganley (2011) (ID531) studied how specific software designed with principles of Universal Design for Learning (UDL) and Curriculum-Based Measurement (CBM) and found positive outcomes on reading of comprehension for students with disabilities in 6-8th grade in the USA (n=84, 73 students with disabilities). (*comprehensive environment*).

### **3.2.2. Mathematics proficiency**

Eight studies in our sample report on positive effects of technology-enhanced curricula on (aspects of) students’ mathematics performance. One study is a meta-analysis covering studies in elementary and secondary education from 19 developing and 66 developed countries (Li &Ma, 2010) (ID206). Three studies are from the USA (Suppes, Holland, Hu, & Vu, 2013) (ID575), (Rochelle et al. (2010) (IDX1), Chappell et al. (2015) (ID38)). The other studies are from Pakistan (Afzal, Gondal, & Fatima, 2014 (ID74), Kenia (Kiboss, 2012) (ID201), India (Kim et al., 2012) (ID208) and Israel (Rosen & Manny-Ikan, 2011) (ID215).

### **Effects of technology applications on student learning in general educational settings**

Li &Ma (2010) (ID206) conducted a meta-analysis covering 46 studies to investigate the impact of technology on mathematics learning. They found a positive, but moderate overall effect of computer technology on mathematics achievement. The effect was higher for elementary education (compared to secondary education), for students with special needs and when constructivist approaches to teaching were applied. Contrary to

the expectations of the researchers, the different types of technology (tools, tutorials, exploratory environments, communication media) did not lead to different effects on mathematics achievement.

Suppes, Holland, Hu and Vu, (2013) (ID575) studied the efficacy of computer-managed individualization of the mathematics curriculum in grade 2 – 5 of elementary school (disadvantaged) students in the USA. Students were matched in pairs (742 pairs, n=1484 students). As a support to regular classroom instruction, the students in the experimental condition worked individually for 20 minutes per day in the computer lab while the control group students followed the regular math program during that time. Curriculum content did not differ between the two groups. The researchers found no significant difference in performance between the experimental and control condition. However, they found that those students in the experimental group who carefully worked on the mathematics exercises on the computer and were engaged, improved more in their mathematics achievement than matched students in the control group. Also students with initially lower mathematics abilities benefited more from the computer-managed individualized curriculum. (*tutorials/drill & practice*)

Roschelle et al. (2010) (ID X1) studied the effect of an exploratory digital mathematics curriculum (SimCalc) on 7<sup>th</sup> and 8<sup>th</sup> grade students' mathematics achievement in the USA (n= 1888) experimental group, n= 1609 control group). The curriculum did not only aim to teach foundational mathematics, but also advanced mathematics using a representational approach to mathematics (*exploratory environment*). Control group students followed the regular curriculum. Findings showed that the experimental students outperformed control group students, in particular on the advanced mathematics part of the test. This study showed that students in a variety of settings learned mathematics at a higher level when teachers used the environment.

### **Equity and opportunity to learn mathematics with technology applications**

Rosen and Manny-Ikan (2011) (ID215) (see also Literacy) also studied the effect of the 'Time To Know' program on mathematics achievement of low SES 5<sup>th</sup> grade students. The findings showed that significant learning gains in mathematics for the experimental groups, especially for the execution of fractions (*comprehensive environment*).

To improve the mathematics achievement (geometry) of hearing impaired students in Kenya, Kiboss (2012) (ID201) developed an e-learning environment (tutorial/drill & practice) and studied its effects on geometry achievement. Students of 9-14 years old in special education schools participated in the study (n=34 experimental group, 32 control group). The results showed that students in the experimental group had significant larger learning gains than the control group students. These students in the experimental group also had a more positive perception of their classroom environment, compared to students in the control group condition who had followed regular (expository) lessons.

In a small-scale study in Pakistan (n=78 students) Afzal et al. (2014) (ID74) studied the effect of technology-enhanced instruction on mathematics achievement in 6<sup>th</sup> grade. They compared three instructional methods: teacher-centered instruction (teacher delivers the curriculum), computer-assisted instruction (students working independently in the computer lab) and computer-supported teacher-facilitated instruction (students work in the computer lab, teachers are present to help students grasp the concepts). They found that low and average achievers in the computer-supported teacher-facilitated instruction method outperformed students who received teacher-centered instruction. The achievements of students in the computer assisted instruction method did not significantly

differ from the other two instruction methods. Also no difference between conditions was found for high achievers (*tutorials/drill & practice*).

Chappell, Arnold, Nunnery and Grant (2015 (ID38) studied the effects of synchronous online tutoring on the mathematics performance on low achieving students in grade 6 (n=49 experimental group, 98 students control group) in the USA. Students in the experimental condition were offered support in a one-to-one learning environment in which chat, instant messaging and virtual whiteboard technology was applied (*communication media*). The study showed that students who were tutored gained significantly in their mathematics achievement.

Kim, Buckner, Kim, Makany, Taleja & Parikh (2012) (ID208) studied the effects of handheld mobile devices on solving numeracy problems for children in marginalized urban and rural communities in India. The software used in the study was a math game (*exploratory environment*). Children (n=210) between 6 – 14 years old participated in the study. The children used the devices without any intervention of adults. Children were observed when using the handheld devices and the number of correct solutions was recorded as an outcome measure. The findings showed that children were able to solve math problems of increasing difficulty. Children playing in groups of 3 performed better than children playing in larger groups (7 children) or individual children. In addition children with access to technology did better than children without much access to technology in their normal daily lives.

### **Effects of technology applications on student learning in other subjects and skills**

Bai, Mo, Zhang, Boswell and Rozelle (2016) (ID430) compared the effects of student independent learning with technology (CAL), and learning with technology integrated in classroom instruction (CAI). The study took place in 5<sup>th</sup> grade in rural schools in the modern foreign languages curriculum in China (CAI: n= 1236 students; CAL n= 1068 students; control group: 4000 students). The findings show that CAI students outperformed the students in the control group that followed traditional instruction. The effects were independent of students' initial performance. Only for high achieving students positive effects were found for CAL students (*tutorial/drill & practice*). Also Rosen and Manny-Ikan (2011) (ID215) (see above) found a positive effect of a teacher facilitated technology intervention (Time To know) on modern foreign language learning for low SES 5<sup>th</sup> grade students.

Singh, Rathakrishnan, Sharif, Talin and Eboy (2016) (ID 2) focused on the use of geography information systems (GIS) in secondary education. They used GIS with underachieving students (n=44 experimental group, n=40 control group). The experimental students received geography using GIS software, while the control group students followed regular instruction. The findings show that students in the experimental group did not only outperformed the students in the control group but also found that they had mastered their learning goals (*exploratory environment*).

1. Klopp, Rule, Schneider and Boody (2014) (ID95) conducted a small-scale study in elementary and middle school science education in the USA. 28 students took part in the curriculum that consisted of two instructional modes: analogy-focused science instruction and independent searches for information using the Internet. All students made two kinds of products to show their learning: technology-rich science products and handmade craft products. Klopp et al. (2014) compared the two instructional modes and the type of products on learning outcomes and the

level of creativity. No differences were found in enjoyment of and interest in learning as well as in students' perceived understanding. Students' level of creativity was higher in the technology-rich products compared to the craft made products, but the craft made products had more science content. In addition students found their craft made products more creative. The researchers argue that it is necessary to offer room for both approaches in the science curriculum (*exploratory environment*).

Eseryel, Ge, Ifenthaler and Law (2011) (ID221) studied the effects of massive multiplayer online games (MMOG) on complex problem solving skills in STEM (Science, Technology, Engineering and Mathematics) education (n= 156 students experimental group, n= 95 control group) in secondary education in the USA. They studied effects of the game on students' problem solving skills and found that the expected conceptual change was not realized, because of cognitive load put upon the students through the game. The researchers argued that cognitive regulation scaffolds are needed to take advantage of the game environment (*exploratory environment*).

Abrami, Venkatesch, Meyer and Wade (2013) (ID108) studied the effect of electronic portfolios (EPs) on students' self-regulation skills in elementary education in Canada (Alberta and Quebec) (n=156 experimental group, n= 165 control group). Teachers in the experimental condition were supported in the use of EPs for developing self-regulation skills. The findings showed that students' self-regulation skills were fostered in classrooms where EPs were implemented at a medium or high level. In addition learning gains were found on a standardized literacy test. (*Comprehensive environment*)

Finally, Kim and Jang (2015) (ID437) studied how the use of tablet PCs influenced students' belief and self-efficacy about the future in rural elementary schools in Korea. Students (n=277) in 4th-6th grade participated in the study. The findings showed that frequency, and ease of use as such, are not sufficient predictors for students' belief in the future and their self-efficacy. Only when students see the use of tablet PCs as useful and want to learn with tablets, beliefs and self-efficacy are positively affected (*comprehensive environment*).

### 3.3. Affordances of technologies

The effects of the technologies described in the previous sections are attributed to affordances of the technologies used. These affordances refer to the characteristics and properties of the technology that allow users (students and teachers) to perform specific actions. Affordances and conditions (see next section) together determine whether and how the expected effects are realized. In this section we describe these affordances of the technologies used in the studies: the reasons and expectations that were reported for studying specific technologies. However, we need to be cautious, because the reasons for using the technology were not always explicitly studied.

#### 3.3.1. Efficient use of learning time

Several studies mentioned efficient use of time as an affordance of the technology. Rasinsky et al. (2011) (ID252) who studied silent reading using specific tool software, argued that an advantage of technology use is that students do not have to listen to other readers, which is common when students read out loud in class. Students using the program will not be distracted by slow readers and thus can use the time for reading much more efficiently. Because each student has its own netbook, Jesson et al. (2015) (ID62)

also mentions increased time for learning as an affordance of personal computers for each child.

### *3.3.2. Student engagement*

Singh et al. (2016) attributed the effects of the GIS environment of students' performance in geography to increased engagement, because the software raises interest and curiosity in learning the topic. In particular because students can more easily follow their own interests. Because of its interactive possibilities technology is a motivational tool that keeps students engaged in their learning (Cave & Yekovich (2010) (ID24); Kiboss (2012) (ID201)). Also Jesson et al. (2015 (ID62)) and Rochelle et al. (2010) (ID X1)) mention increased engagement of students a reason for using technology. Rosen and Maney-Ikan (2011) also refer to increased motivation and engagement as a possible explanation for the learning effects as well, but they also wondered whether this might be a novelty effect.

### *3.3.3. Independent learning*

Suppes et al. (2013) (ID 575), in studying the effects of an individualized computer managed mathematics curriculum, argued that technology makes it possible to individualize learning, in particular when the software is based on a dynamic learning model. Kartel and Terziyan (2016) (ID 436), when studying phonological awareness in kindergarteners mention the individual pace that the software allows as one of the affordances of the use of technology. The Time to Know curriculum (Rosen & Maney-Ikan (2011) (ID213)) that was implemented in low SES schools in Israel alluded to the possibility to differ in learning materials and support for the same topic, in order to optimally support students in their learning.

### *3.3.4. Learning-focused interactions*

Wilson et al. (2014) (ID86), who studied the effects of automated feedback on the quality of the writing, reported that the automated feedback allowed students to be exposed to feedback on their writing, resulting in increased learning-focused interactions. Likewise, Suppes et al. (2013) (ID575) perceived feedback, reinforcement and concrete hints as affordances of the technology used in their study on mathematics learning. The online tutors in the study of Chappell et al. (ID 38) attributed the positive effects of online synchronous tutoring to the ongoing monitoring of student progress and the guided practice that they offered. Kartel and Terziyan (2016) (ID 436) mentioned two characteristics of the environment they designed to account for the learning effects on kindergarteners: immediate feedback and user control. Similarly, Jesson et al. (2015) mentioned the increase in interactions to support learning and Cave and Yekovich, (2010) (ID24) referred to the possibility to practice skills.

### *3.3.5. Safe environment*

In their study about silent reading, Rasinsky et al. (2011) (ID252) mentioned that the digital environment that supports students in their reading offers a safe space for students who are not fluent in reading. Likewise, Eseryel et al. (2011) (ID221) mentioned the possibility to solve problems in the safety of a virtual practice world (p. 277) as an affordance of game technology.

### ***3.3.6. Authentic learning environment***

Kartel and Terziyan (2016) (ID 436) created a meaningful context for developing phonological awareness skills and argued that this was important for the positive effects that were found. Likewise, Eseryel et al. (2011) stated that practicing problem solving skills in real-life professional situations is important and that games can provide such environments for use in education. The use of computers contributed to the authenticity of the newsroom as environment for writing (Cave & Yekovich, 2010) (ID24). Kim et al. (2012) (ID208), in their study on the use of handheld mobile devices with students from poor backgrounds in India, referred to the possibility to give students the experience of being a young scientist in charge of solving problems with peers as an affordance of the technology. Rochelle et al. (2010), in their study on middle school mathematics in the US mentioned the possibility to easily build mathematical models, which makes it relatively easy to relate mathematics to real life contexts.

### ***3.3.7. Variety in representations***

Kiboss (2012) (ID 201), in his study on hearing impaired students, mentioned the use of different visual representations in presenting information through the technology – both in text and sign language – to support hearing impaired learners. Likewise, Rochelle et al. (2010) (ID X1) mentioned the possibility to use different representations an important affordance of technology. This was also reported by Chappel et al. (2015) (ID38) about their study on online synchronous tutoring to foster mathematics achievement in low achieving students. One reason for the success of the program was, according to Chappell et al. (2015), that the variety of mathematical representations helped to build conceptual understanding.

## **3.4. Conditions for effective implementation**

### ***3.4.1. Curriculum integration and pedagogical alignment***

Several studies mentioned the need to integrate technology in the curriculum and align it with pedagogy in order to obtain the expected effects. Bai et al. (2016) (ID430) compared technology use that was integrated in the curriculum with non-integrated use of technology. They concluded that learning effects of technology could only be expected when the software is an integrated part of the curriculum. This is in particular important when students start to learn a subject. Only when students have good foundational knowledge, students may be able to use technology for independent learning. Likewise, Rochelle et al. (2010) (IDX1) concluded that the integration of the digital environment in the initial mathematics curriculum accounted for the effects that were found.

Li and Ma (2010), in their meta-analysis of studies about the use of technology for mathematics learning, found higher effects when constructivist approaches to teaching were applied compared to more traditional forms of teaching. They also found that shorter interventions had more impact than longer programs. Li and Ma (2010) suggest that this might be due to a novelty effect and recommend to arrange for variety and breaks in the use of technology. Kim et al. (2012) (ID208) argue for the importance of an inquiry-based pedagogy when using mobile devices with young children as well. In their study, children who worked in groups of three formulated more and better solutions to the problems offered than those children who worked on their own or in larger groups. Rochelle et al. (2010) (ID X1) recommended pedagogy in which students are actively involved because they are required to compare predictions with mathematical reality.



Eseryel et al. (2011) (ID221) point to the need to offer scaffolds to students who have to solve complex problems in a game environment, to help them construct mental representations of the problem so that they know what they are doing. Klopp et al. (2014) (ID 95) advocates learning environments, which not only consist of technology but also offer the possibility for children to craft their own three-dimensional products. Because the construction of such products contributes to pattern recognition, which is an important science skill, they argue that this is particularly important in science education.

### ***3.4.2. Roles and support for teachers***

Several studies emphasized the active role of teachers when technology is used to support student learning. According to Rosen & Maney-Ikan (2011) (ID213), a partnership between the technology and the teacher is created in the Time to Know program. The digital environment helps the teacher to facilitate the learning of the students. The teacher receives materials for their lessons and assessment reports (formative and summative) to monitor progress from the environment, but based on experiences with their students they can also easily change the materials and sequences offered in the digital environment when they see a need for it. Bai et al. (2016) (ID430) mentioned how important it is that teachers are able to scaffold students' learning with the technology in classroom interactions in which practical and actual experiences with English as a foreign language are provided to pursue the educational goals. Similarly, Afzal et al. (2014) in their study about technology use for mathematics learning in Pakistan pointed to the responsibility of teachers to support student in learning with the software, in particular for low and average achievers.

Because of the important role of teachers in integrating technology in the curriculum, teachers need to be supported to be able to implement the technology as intended. Rochelle et al (2010) (IDX1) provided professional development to teachers who had to implement the technology-enhanced mathematics curriculum, so that teachers knew how to use the specific features of the curriculum. Also in the Time to Know program, teachers were offered pedagogical and technical support (Rosen & Many-Ikan, 2011) (ID213). The teachers took part in professional development and received ongoing support during the implementation of Time to Know.

### ***3.4.3. Opportunities and concerns from an equity perspective***

Several studies mention the importance of the *design* of technology applications for the inclusion of all learners. Hall et al. (2011) (ID531) point to Universal Design for Learning (UDL) principles for the design of software to anticipate a variety of learners. UDL takes care of 1) multiple representations to deal with physical, perceptual and cognitive barriers that might impede learning; 2) multiple means for action and expression to recognize the variability in which learners express themselves and perform learning tasks and 3) multiple means of engagement. Also Kiboss (2012) (ID 201) mentioned the principle of multiple representations in his study about hearing-impaired students.

Heemskerk, ten Dam, Volman, & Admiraal (2009) (ID330) studied how technological applications can offer different opportunities for learning, because of the underlying scripts guiding the design. According to the authors "Scripts can be defined as assumptions about a supposed user that become an integrated part of the entire process of technological development" (p. 255). Such scripts can be found in the content of the technology application, the interface (both referring to design) and the instructional structure (referring to the use in educational practice) in which the application is being

used. Technology tools that are not strongly scripted are considered inclusive. They studied technology applications on gender-related scripts for several subjects and found that inclusive technology applications were beneficial for both boys and girls, while less inclusive technology applications especially served the learning of boys.

Several concerns were expressed with the implications of technology use, particularly for schools in rural areas and for schools with many students with low socio economic backgrounds. Courtney and Anderson (2010) (ID262) mentioned problems with the maintenance of the hardware particularly in rural schools. De la Varre, Irvin, Jordan, Hannum and Farmer (2014) (ID 80) referred to the large amount of students, particularly in rural areas, who enroll in online courses to prepare themselves for further education. These students, according to De la Varre et al. (2014), need local support to prevent them from dropping out.

Based on the experiences with the Time to Know program in low SES schools, Rosen and Maney-Ikan (2011) (ID213) concluded that it took time for both students and teachers to adapt to the technology and therefore, implementation of technology is more challenging in such an environment. Fishman, Penuel, Hegedus and Roschelle (2011) (ID215) found in their study on the sustainability of the digital math curriculum (Roschelle et al., 2010) that additional professional development may be needed especially in low SES schools or in settings where student performance is low in order to sustain the use of technology over time.

- Students' perceptions of technology use

Students are not always excited about the use of technology to support their learning. High and middle school students (Stefl-Mabry, Radlick & Doane, 2010) (ID256) They found that secondary school students in the US were annoyed with not being able to use personal devices in class and the limited access to internet. In addition, they did not find their teachers prepared to teach with technology. They wanted to be actively involved and were willing to do extra work if learning is adapted to their interests. The findings of Courtney and Anderson (2010)(ID262) of secondary school students in Australia were quite similar. Students were asked to compare school technology use with home computer use and found computer tasks at school boring, were irritated about slow or blocked internet connections at school and were not dissatisfied because they were not allowed to multi-task. Kim and Jang (2015) (ID437), in their study about the use of tablet PCs in elementary education in Korea, showed that students' positive view on technology was not related to frequency of use, but to the extent students find the technology applications useful. De la Varre et al. (2014) (ID80) found that students in online courses may easily drop out when there are technological problems and if there are scheduling and time constraints. In addition to these factors, students needed to be motivated and supported by teachers and parents to successfully study in online environments.

#### ***3.4.4. Scaling and Sustainability***

Fishman et al. (2011) (ID215) focused in their study on the sustained use of a math curriculum (Roschelle et al. (2010) (ID X1). They found that coherence and utility were both related to sustained use. Coherence in this study is conceptualized as the alignment of the professional development offered to teachers to implement the digital math curriculum with teachers' own learning goals, the pedagogical approaches in their school and follow up activities that help to implement the curriculum. Utility referred to teachers' style of teaching and the perceived capabilities of their students. Jesson et al. (2015) (ID62) emphasized the importance of research-teacher partnership to implement

and scale 1:1 netbooks in elementary schools in New Zealand. The partnership in their study was based on shared objectives focusing on student achievement and the use of data to improve practices. Because of the partnership, researchers observed the classrooms in which the netbooks were used and distinguished teaching approaches that reinforced the affordances of the technology. Knowledge about the most reinforcing teaching approaches was then shared with participating teachers, resulting in more teachers being able to use the technology in ways that foster student achievement.

#### 4. Summary and conclusions

This review of the literature aimed to answer the following question “What is the impact of technology in realizing curriculum quality and equity and equal opportunities for learning, and what is needed to effectively implement technology to realize this impact?” To answer this question we reviewed a sample of studies that were recently published and conducted in a variety of jurisdictions.

The studies in our dataset reported effects of technology-based interventions that contributed to student learning. Most studies focused on student learning in literacy and mathematics. The studies about technology use in literacy education focused on improvement of student writing and fostering student reading skills, with regard to fluency and comprehension. The studies about technology use in mathematics education covered a broader variety of topics, but predominantly focused on the possible contribution of technology to students’ conceptual understanding and procedural skills. Only a few studies in our sample covered student learning with the help of technology in other domains than literacy and mathematics, viz. science, geography and modern foreign language and skills (creativity, problem solving and self-regulation). The studies in our dataset showed that technology could be used to contribute to curriculum rigor: developing conceptual understanding, fostering procedural skills and fluent application of concepts.

From an equity perspective, several studies in our dataset showed that technology use could positively contribute to the learning of low achieving students, students from low SES backgrounds, students from rural settings, students from developing countries and students with disabilities.

The evidence on positive impact of technology on student learning is not undisputed. Several studies showed that technology had no effect or even a negative effect on student learning. For instance, the study of Dynarski et al. (2007), presented to the US Congress, showed that commercial software – in particularly computer assisted instruction type of software for reading and mathematics - did not affect student performance on standardized tests for reading and mathematics. In their meta-analysis, Cheung and Slavin (2012) (IDX2) showed similar findings as Dynarski et al. (2007) for computer assisted instruction software for reading, but they found higher effect sizes for technology applications for reading that were integrated in the classroom. Cheung and Slavin (2012) concluded that computer-assisted instruction, which is used most in educational practice, did not seem to provide the expected effects. Also the recent study of the OECD (2015)

“student, computers and learning – making the connection” was rather negative about the effects of technology use for student performance in mathematics, reading and science, in particular in countries that seem to have investigated a lot in ICT. They also reported disappointing findings about technology use and equity. In their study, the use of technology did not serve to decrease the gap between advantaged and disadvantaged students. These studies show that research is needed to better understand under which conditions positive effects of technology on student learning can be realized and sustained beyond research settings, in normal schools and classrooms (cf. Voogt & Knezek, 2008).

This study also has its limitations. Only a limited number of recent studies were included in the dataset, which might have resulted in a limited view on the contribution of technology to curriculum quality and equity. Positive, however, is that a fairly large number of students were included in the data set and that next to the US a variety of countries were involved. In addition, the variety of study designs (RCT, meta-analysis, mixed methods and experiments) made it possible to not only focus on effects of technology, but also on affordances and conditions for implementation. The duration of the studies in our data set differed a lot and, for many of the studies in our sample, it turned out to be difficult to calculate the time students were really learning with technology. We do not know yet how the use of technology and face-to-face interactions in the classroom can best be organized. For this reason, a better understanding of the time of the technology-related interventions would have been useful. Cheung and Slavin (2012) found in their study that effect sizes of singular studies were higher than effect sizes that result from meta-analysis. Effect sizes were not always reported in the studies in our dataset, but this finding of Cheung and Slavin (2012) might also be true for the studies in our dataset. In this regard the findings in this review need to be interpreted with caution.

Increasingly, research on technology in education is not only interested in the effects of technology use, yet also in the characteristics of the technology responsible for the effect and the conditions under which the effects are realized. In our review, the researchers attributed the effects on student learning on several affordances of the technology. Most frequently mentioned was the increase in learner-focused interactions (6x) and student engagement (6x), followed by the possibility to create authentic learning environments for students (5x). The possibility to provide a variety in representations (which also benefits students with disabilities) was mentioned 3 times. Efficient use of learning time and a safe environment for learning was mentioned twice. More research is needed on how exactly these affordances contribute to student learning and how the various affordances of technology interact with each other.

In the studies in our dataset, several conditions were mentioned for the effects to take place. The most important condition was the integration in the curriculum and alignment with pedagogy (6x). Some studies even showed that lack of integration (e.g. Bai et al., 2016) with the curriculum and lack of alignment with pedagogy (e.g. Li & Ma, 2010) resulted in no effects of technology on student learning (cf. Eickelmann (2011)). This directly relates to the important role of teachers and their use of technology in their teaching (4x). In addition, when students are expected to learn with the technology independently, teachers still need to teach. Often teachers need support on how to best teach with technology (e.g. Rosen & Maney-Ikan, 2011; Roschelle et al. 2010). A focus on teachers is also important from the perspective of sustainability and scaling (2x) of technology-related innovations. Finally, not only teachers need to learn to work with the technology, this also accounts for students (4x). According to students, technology use in

schools is boring (e.g. Courtney & Anderson, 2010). Students who are dependent on technology for their learning, such as students in online learning settings, need support from teachers and parents in order to prevent drop out (De la Varre et al., 2014). Opportunities and concerns from an equity perspective are mentioned 7 times. In particular these opportunities and concerns are related to the design of and access to technology.

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## *Appendix 1*

### 1. Search Technology in Education

**Research question:** What is the impact of technology in realizing curriculum quality and equity and equal opportunities for learning, and what is needed to effectively implement technology to realize this impact? (OECD2030 project)

#### Databases

ERIC	421 results (March 21, 2017)
Web of Science	56 results (March 21, 2017)
PsycINFO	204 results (March 21, 2017)
Total	681 results
Total, deduplicated	639 results

#### ERIC

*Ovid, 1965 to January 2017*

- Technology

access to computers/ OR blended learning/ OR computer assisted instruction/ OR computer assisted testing/ OR computer mediated communication/ OR educational media/ OR educational technology/ OR handheld devices/ OR influence of technology/ OR integrated learning systems/ OR intelligent tutoring systems/ OR laptop computers/ OR multimedia materials/ OR online courses/ OR social media/ OR technology integration/ OR technology uses in education/ OR open source technology/ OR (blended learning OR educational media OR flip\* classroom\* OR ICT\* OR ipad\* OR laptop\* OR multimedia OR online OR on-line OR social media OR tablet\* OR makerspace\* OR maker movement\* OR open source OR raspberry pi).ti,ab,id.

#### Results: 120.882

- Curriculum & Instruction

elementary school curriculum/ OR secondary school curriculum/ OR curriculum/ OR instruction/ OR direct instruction/ OR instructional effectiveness/ OR teaching methods/ OR curriculum implementation/ OR experimental curriculum/ OR virtual classrooms/ OR distance education/ OR individualized instruction/ OR cooperative learning/ OR (curricul\* OR teaching method\* OR instruction\* OR virtual school\* OR distance learning OR distance education OR adaptive learn\* OR personali\*ed learn\* OR formal learn\* OR informal learn\* OR individualized instruction OR individualized learning OR self-paced instruction OR differentiated instruction OR self-paced learn\* OR differentiated learn\* OR cooperative learn\*).ti,ab,id.



**Results: 450.142**

- Equity

rural schools/ OR special needs students/ OR special education/ OR academically gifted/ OR socioeconomic status/ OR (rural school\* OR special needs OR special education OR gifted student\* OR soci\* economic status OR SES OR (gender ADJ3 (equity OR equal\* OR opportun\* OR inequit\* OR gap\* OR unequal\*))).ti,ab,id.

**Results: 72.907**

- K12

(elementary secondary education OR grade 1 OR grade 2 OR grade 3 OR grade 4 OR grade 5 OR grade 6 OR grade 7 OR grade 8 OR grade 9 OR grade 10 OR grade 11 OR grade 12 OR elementary education OR primary education OR intermediate grades OR middle schools OR junior high schools OR secondary education OR high schools).el. OR elementary secondary education/ OR grade 1/ OR grade 2/ OR grade 3/ OR grade 4/ OR grade 5/ OR grade 6/ OR grade 7/ OR grade 8/ OR grade 9/ OR grade 10/ OR grade 11/ OR grade 12/ OR elementary education/ OR elementary schools/ OR primary education/ OR public schools/ OR middle schools/ OR junior high schools/ OR secondary education/ OR secondary schools/ OR high schools/ OR (elementary education OR elementary school\* OR primary education OR primary school\* OR K-12\* OR K12 OR 1st-grade\* OR first-grade\* OR grade 1 OR grade one OR 2nd-grade\* OR second-grade\* OR grade 2 OR grade two OR 3rd-grade\* OR third-grade\* OR grade 3 OR grade three OR 4th-grade\* OR fourth-grade\* OR grade 4 OR grade four OR 5th-grade\* OR fifth-grade\* OR grade 5 OR grade five OR 6th-grade\* OR sixth-grade\* OR grade 6 OR grade six OR intermediate general OR secondary education OR secondary school\* OR 7th-grade\* OR seventh-grade\* OR grade 7 OR grade seven OR 8th-grade\* OR eight-grade\* OR grade 8 OR grade eight OR 9th-grade\* OR ninth-grade\* OR grade 9 OR grade nine OR 10th-grade\* OR tenth-grade\* OR grade 10 OR grade ten OR 11th-grade\* OR eleventh-grade\* OR grade 11 OR grade eleven OR 12th-grade\* OR twelfth-grade\* OR grade 12 OR grade twelve OR junior high\* OR highschool\* OR preuniversity OR pre-university).ti,ab.

**Results: 575.799**

**1 AND 2 AND 3 AND 41.863 results**

**Limit to peer review 596 results**

**Limit to 2005- 421 results**

**PsycINFO**

*Ovid, 1806 to March Week 2 2017*

- Technology

computer assisted instruction/ OR computer assisted testing/ OR computer mediated communication/ OR instructional media/ OR mobile devices/ OR intelligent tutoring systems/ OR social media/ OR (blended learning OR educational media OR flip\* classroom\* OR ICT\* OR ipad\* OR laptop\* OR multimedia OR online OR on-line OR social media OR tablet\* OR makerspace\* OR maker movement\* OR open source OR raspberry pi).ti,ab,id.

**Results: 94.121**

- Curriculum & Instruction

curriculum/ OR teaching methods/ OR virtual classrooms/ OR distance education/ OR individualized instruction/ OR cooperative learning/ OR (curricul\* OR teaching method\* OR instruction\* OR virtual school\* OR distance learning OR distance education OR adaptive learn\* OR personali\*ed learn\* OR formal learn\* OR informal learn\* OR individualized instruction OR individualized learning OR self paced instruction OR differentiated instruction OR self paced learn\* OR differentiated learn\* OR cooperative learn\*).ti,ab,id.

**Results: 177.384**

- Equity

special education/ OR special education students/ OR special needs/ OR gifted/ OR socioeconomic status/ OR gender equality/ OR gender gap/ OR (rural school\* OR special needs OR special education OR gifted student\* OR soci\* economic status OR SES OR (gender ADJ3 (equity OR equal\* OR opportun\* OR inequit\* OR gap\* OR unequal\*))).ti,ab,id.

**Results: 90.623**

- K12

(school age 6 12 yrs OR adolescence 13 17 yrs).ag. OR elementary education/ OR elementary schools/ OR elementary school students/ OR primary school students/ OR public school education/ OR middle schools/ OR middle school education/ OR middle school students/ OR junior high schools/ OR junior high school students/ OR secondary education/ OR high schools/ OR high school students/ OR high school education/ OR (elementary education OR elementary school\* OR primary education OR primary school\* OR K-12\* OR K12 OR 1st-grade\* OR first-grade\* OR grade 1 OR grade one OR 2nd-grade\* OR second-grade\* OR grade 2 OR grade two OR 3rd-grade\* OR third-grade\* OR grade 3 OR grade three OR 4th-grade\* OR fourth-grade\* OR grade 4 OR grade four OR 5th-grade\* OR fifth-grade\* OR grade 5 OR grade five OR 6th-grade\* OR sixth-grade\* OR grade 6 OR grade six OR intermediate general OR secondary education OR secondary school\* OR 7th-grade\* OR seventh-grade\* OR grade 7 OR grade seven OR 8th-grade\* OR eight-grade\* OR grade 8 OR grade eight OR 9th-grade\* OR ninth-grade\* OR grade 9 OR grade nine OR 10th-grade\* OR tenth-grade\* OR grade 10 OR grade ten OR 11th-grade\* OR eleventh-grade\* OR grade 11 OR grade eleven OR 12th-grade\* OR twelfth-grade\* OR grade 12 OR grade twelve OR junior high\* OR highschool\* OR preuniversity OR pre-university).ti,ab.

**Results: 573.695**

**1 AND 2 AND 3 AND 4362**

**Limit to 2005-**

**204 results**

**Web of Science**

- Technology

TS=("blended learning" OR "educational media" OR "flip\* classroom\*" OR "ICT\*" OR "ipad\*" OR "laptop\*" OR "multimedia" OR "online" OR "on-line" OR "social media"

OR "tablet\*" OR "makerspace\*" OR "maker movement\*" OR "open source" OR "rasberry pi")

**Results: 372.491**

- Curriculum & Instruction

TS=("curricul\*" OR "teaching method\*" OR "instruction\*" OR "virtual school\*" OR "distance learning" OR "distance education" OR "adaptive learn\*" OR "personali\*ed learn\*" OR "formal learn\*" OR "informal learn\*" OR "Individualized Instruction" OR "Individualized learning" OR "Self Paced Instruction" OR "Differentiated Instruction" OR "self paced learn\*" OR "differentiated learn\*" OR "cooperative learn\*")

**Results: 171.510**

- Equity

TS=("rural school\*" OR "special needs" OR "special education" OR "gifted student\*" OR "soci\* economic status" OR "SES" OR ("gender" NEAR/2 ("equity" OR "equal\*" OR "opportun\*" OR "inequit\*" OR "gap\*" OR "unequal\*")))

**Results: 45.017**

- K12

TS=("elementary education" OR "elementary school\*" OR "primary education" OR "primary school\*" OR "K-12\*" OR "K12" OR "1st-grade\*" OR "first-grade\*" OR "grade 1" OR "grade one" OR "2nd-grade\*" OR "second-grade\*" OR "grade 2" OR "grade two" OR "3rd-grade\*" OR "third-grade\*" OR "grade 3" OR "grade three" OR "4th-grade\*" OR "fourth-grade\*" OR "grade 4" OR "grade four" OR "5th-grade\*" OR "fifth-grade\*" OR "grade 5" OR "grade five" OR "6th-grade\*" OR "sixth-grade\*" OR "grade 6" OR "grade six" OR "intermediate general" OR "secondary education" OR "secondary school\*" OR "7th-grade\*" OR "seventh-grade\*" OR "grade 7" OR "grade seven" OR "8th-grade\*" OR "eight-grade\*" OR "grade 8" OR "grade eight" OR "9th-grade\*" OR "ninth-grade\*" OR "grade 9" OR "grade nine" OR "10th-grade\*" OR "tenth-grade\*" OR "grade 10" OR "grade ten" OR "11th-grade\*" OR "eleventh-grade\*" OR "grade 11" OR "grade eleven" OR "12th-grade\*" OR "twelfth-grade\*" OR "grade 12" OR "grade twelve" OR "junior high\*" OR "highschool\*" OR "preuniversity" OR "pre-university" OR "child\*" OR "adolesc\*" OR "boy\*" OR "girl\*" OR "youth")

**Results: 155.783**

**1 AND 2 AND 3 AND 463**

**Limit to 2005-**

**56 results**

## Appendix 2

**Figure 1.1.**

Author	Title	Juris-diction	Educational sector	Methodology	Nr of subjects	Quality of curriculum content	Equity/opportunity of learning	Effective implementation
Singh et al. 2016	The Effects of Geography Information System (GIS) Based Teaching on Underachieving Students' Mastery Goal and Achievement	Malaysia	Secondary	Mixed methods	84	Yes	Ability	No
Cave & Yekovich, 2010	The Effect of TRALE (Technology-Rich Authentic Learning Environments) on Young Urban Learners' Intentionality in Writing	US	Elementary	Experiment	37	Yes	Special Needs	No
Chappell et al., 2015	An Examination of an Online Tutoring Program's Impact on Low-Achieving Middle School Students' Mathematics Achievement	US, Virginia	Elementary	Mixed Methods	119	No	Ability	Yes
Jesson et al., 2015	Raising Literacy Levels Using Digital Learning: A Design-Based Approach in New Zealand	New Zealand	Elementary	Mixed methods	443	Yes	Ability, SES	Yes
Afzal et al., 2014	The Effect of Computer Based Instructional Technique for the Learning of Elementary Level Mathematics among High, Average and Low Achievers	Pakistan	Elementary	Experiment	78	No	Ability	Yes
De la Varre et al., 2014	Reasons for Student Dropout in an Online Course in a Rural K-12 Setting	29 states in US	Secondary	Qualitative	720	Yes	Rural	Yes
Wilson et al., 2014	Does Automated Feedback Improve Writing Quality?	US	Elementary/Secondary	Quantitative	955	Yes	Gender, SES	Yes
Klopp et al., 2014	Computer Technology-Integrated Projects Should Not Supplant Craft Projects in Science Education	US	Elementary/Secondary	Mixed methods	28	Yes	No	Yes
Abrami et al.	Using Electronic Portfolios to Foster Literacy and Self-Regulated Learning Skills in Elementary Students	Canada	Elementary	Experiment	319	Yes	No	No
Kiboss, 2012	Effects of Special E-Learning Program on Hearing-Impaired Learners' Achievement and Perceptions of Basic Geometry in Lower Primary Mathematics	Kenya	Elementary/Secondary	Experiment	66	Yes	Ability	Yes
Li & Ma, 2010	A Meta-Analysis of the Effects of Computer Technology on School Students' Mathematics Learning	85 different countries	Elementary/Secondary	Meta-analysis	36.793	Yes	Ability	Yes
Kim et al., 2011	A Comparative Analysis of a Game-Based Mobile Learning Model in Low-Socioeconomic Communities of India	India	Elementary/Secondary	Mixed Methods	210	Yes	SES	Yes
Rosen & Manny-Ikan,	The Social Promise of the Time to Know Program	Israel	Elementary	Experiment	91	No	SES	No

2011								
Fishman et al., 2011	What Happens when the Research Ends? Factors Related to the Sustainability of a Technology-Infused Mathematics Curriculum	US	Elementary/ Secondary	Quantitative	189*	Yes	No	Yes
Eseryel et al., 2011	Dynamic Modeling as a Cognitive Regulation Scaffold for Developing Complex Problem-Solving Skills in an Educational Massively Multiplayer Online Game Environment	US	Secondary	Experiment (2 studies)	251 & 280	Yes	No	Yes
Rasinski et al., 2011	The Relationship between a Silent Reading Fluency Instructional Protocol on Students' Reading Comprehension and Achievement in an Urban School Setting	US, Florida	Secondary	Experiment	16.143	Yes	Ability	Yes
Steff-Mabry et al., 2010	Can You Hear Me Now? Student Voice: High School & Middle School Students' Perceptions of Teachers, ICT and Learning	US	Secondary	Mixed methods	1128	Yes	No	Yes
Courtney, & Anderson, 2010	Do Rural and Regional Students in Queensland Experience an ICT "Turn-Off" in the Early High School Years?	Australia	Secondary	Mixed Methods	629	No	No	Yes
Heemskerk et al., 2009	Gender Inclusiveness in Educational Technology and Learning Experiences of Girls and Boys	Netherlands	Secondary	Mixed Methods	111	No	Gender	No
Bai et al., 2016	The impact of integrating ICT with teaching: Evidence from a randomized controlled trial in rural schools in China	China	Elementary	RCT	6304	Yes	No	Yes
Kartal & Terziyan, 2016	Development and Evaluation of Game-Like Phonological Awareness Software for Kindergarteners: JerenAli	Turkey	Elementary	Experiment	20	Yes	Ability	No
Kim & Jang, 2015	Factors influencing students' beliefs about the future in the context of tablet-based interactive classrooms	Korea	Elementary	Quantitative	277	Yes	No	Yes
Hall et al., 2015	Addressing learning disabilities with UDL and technology: Strategic reader.	US	Secondary	Experiment	284	Yes	Special Needs	No
Suppes et al., 2013	Effectiveness of an individualized computer-driven online math K-5 course in eight California Title I elementary schools.	US	Secondary	Experiment	1484	Rigor	Ability	No
Roschelle, et al., 2010	Integration of Technology, Curriculum, and Professional Development for Advancing Middle School Mathematics: Three Large-Scale Studies	US	Secondary	RCT	3494	Rigor	no	Yes
Cheung & Slavin, 2012	How features of educational technology applications affect student reading outcomes: A meta-analysis.	660553	Elementary/ Secondary	Meta analysis	660553	Yes	Yes	Yes