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The Contribution of Student-Centered Pedagogy to the Effective Use of Educational Technology: A Meta-Analysis

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ABSTRACT

It is no longer a question whether technology should be integrated into the classroom. The focus has shifted to how to use it to enable and promote effective learning. For better or for worse, technology is pervasive in our lives, and educational settings are no exception. However, it is not sufficient to employ educational technology simply because it is available. How technology is deployed, when and for what purposes it is used, what kind of learning it is applied to, and which categories of students it affects, are now of prime importance. This paper presents findings of a meta-analysis (M-A) that investigated differences between teacher-centered and student-centered (T-C vs. S-C) pedagogical practices in their effect on educational technology use as measured by student achievement outcomes. To describe S-C strategies, eleven instructional dimensions were identified from our previous work. Findings, based on 168 independent effect sizes (ESs) comparing T-C with S-C revealed a weighted average of g+=0.402 indicating that educational technology moderately increases learning achievement outcomes. Significant findings are reported, with four dimensions -*Course design, Problem type, Conceptual level,* and *Peer collaboration* - strengthening the impact of educational technology on students' achievement, and in one dimension - *Pacing/Flexibility* - weakening it.

KEYWORDS

Student-centered instructional practices; teacher-centered instructional practices; educational technology; learning achievement outcomes; meta-analysis.

Introduction

One might easily think of students from the technological age as "digital natives" – a term used by several theorists, but most notably, Marc Prensky (Hattie & Yates, 2014). The main argument is that today's students process information in a fundamentally different way than "digital immigrants" (i.e., those not born into a world where technology is always available). Considering this, the temptation might arise to use technology with our students for its own sake (i.e., because it's there) rather than establishing if and how its use contributes to learning outcomes in both natives and immigrants. Employing educational technology does not automatically lead to better learning – a point the authors aim to make clear in this paper. The "digital native" concept has largely been debunked, mainly because it has been difficult to prove that young people's thinking is fundamentally altered, and their learning is invariably enhanced by the presence of ubiquitous technology from birth onward. However, there might be some merit to the theory, understanding that the term should be used with caution. There seems to be something intuitive about wanting to impart knowledge to the younger generation in a way that will "speak" to them. This hunch is not misguided, but it is simply best when informed by research evidence.

The notion of student-centered (S-C) teaching is not new. The concept is largely rooted in the ideas of the social construction of knowledge proposed and elaborated by Vygotsky (for an overview of his earlier work see Gredler, 2012; Land & Jonassen, 2012; Tobias & Duffy, 2009). In connection to educational technology, the ideas were pioneered by Hannafin and Land (2000). According to them, the movement towards S-C pedagogy was initially facilitated by the ubiquitous presence of technology, not just in the classroom but everywhere. Information on demand and the ease and accessibility of content creation for all spurred the growth of the movement, encouraging teachers to embrace a whole new way of teaching. With such a change in technological advances, one might naturally expect a drastic impact on educational practices. However, this has not been the case. Where once teaching was accomplished without technology, in most cases, the same pedagogical methods are still used, only now with the aid of technology (e.g., presentations using an overhead projector rather than a blackboard). However, the immense potential of educational technology, for the most part, has yet to be harnessed.

Hannafin and Land explain in-depth and exemplify the difference between a S-C teaching approach and a more traditional instruction directed by teachers. They also describe the challenges, as well as the potential of such approaches. They argue that it is not about embracing the new and discarding the old. Rather, it is about determining which approach should be used for what purpose. S-C teaching can be challenging for any professional, but perhaps more so for seasoned teachers who have learned and practiced traditional teaching methods for many years. S-C teaching emphasizes what the student learns rather than what the teacher teaches. With traditional methods, students are taught to rely upon and look to the teacher for instruction, encouragement and guidance in their learning, a very different perspective from more S-C teaching that places the student in an active, generative role in their learning.

With these elements in mind and a better understanding of S-C learning, the goal of the current paper is to inform educators and policymakers more broadly about how the use of educational technology informed by pedagogy may better serve student learning and target teaching goals.

Rationale and focus

The debate about the transformative power of educational technology between its critics (e.g., Clark, 1994) and its proponents (e.g., Kozma, 1991) has largely been settled (e.g., Bernard et al. 2004). Educational technology is not limited to being just a teaching vehicle, it can lighten the cognitive load related to learning and, thus, facilitate knowledge acquisition (e.g., Schmid et al., 2014). However, the exact conditions that moderate the effects of educational technology on student achievement outcomes remain somewhat unclear (e.g., Ross et al., 2010).

One of the main findings of a large-scale M-A conducted by Schmid et al. (2014) pertains to the cognitive support to student learning that effective educational technology can provide. A positive influence on student achievement outcomes was found when this type of educational technology was used alone (g^{+}=0.40, *k*=56) or in various combinations (g^{+}=0.53, *k*=30). Cognitive support proves to be more effective than other functions (e.g., content presentation: g^{+}=0.17, *k*=65). This is not to say, however, that to improve learning it would be sufficient simply to employ an appropriate cognitive support tool. On the contrary, the risk of misusing such technology is greater than with more straightforward presentation tools, as demonstrated by the spread of effect sizes (ES) in these categories. The former distribution contained both highly positive (e.g., *g*=+2.30, Issenberg et al., 2002) and negative ESs (e.g., *g*=–1.23, Mäkitalo et al., 2004), whereas the latter was tighter, with the ESs clustering around the mean.

Educational technology is more likely to be effective when used by students to achieve learning objectives, rather than when used by teachers to present/illustrate study materials, a sentiment shared by Cobb (1997) about the role that educational technology should play in affording students' *cognitive efficiencies*. Specifically, there is collaboration at work in most learning situations, shared cognition between the learner, the content to be learned and the tools employed to arrive at this learning (e.g., Jonassen, 2000; Bernard et al., 2009). Technology should be a learning aid, resulting in a reduction of the student's extraneous cognitive load.

Several reviews have focused on specific teaching strategies such as the *social construction of knowledge*, *discovery learning*, or *problem-based learning*. However, none have approached the task from an overall S-C perspective. This is related to the highly complex nature of educational technology and the challenges its operationalization presents. Also, there is a vast array of educational technology now in use and emerging continuously. Not all technology was included in the current review; the emphasis was placed on educational technology solutions that have plateaued and proven to be effective, according to Gartner's *hype cycle* (Linden & Fenn, 2003; Tamim et al., under review).

Variability in educational technology effectiveness

Research evidence suggests that educational technology is generally effective across classroom settings and learning tasks (e.g., second-order M-As by Tamim et al., 2011; Borokhovski et al., 2022). However, this effectiveness can vary considerably. Technology should be used as a vehicle for learning – i.e., as a means of facilitating pedagogical goals. Some recent research findings generally point to positive and significant, though low-to-moderate ESs when technology is used for educational purposes. However, despite technological improvements, these effects are neither homogeneous nor have they been shown to increase over time (Schmid et al., 2014). This heterogeneity presents important challenges for educational practitioners when selecting and adopting educational technology solutions in their teaching. With the above in mind, the authors decided to focus the current M-A on the effectiveness of educational technology on student learning outcomes using their established framework of instructional dimensions.

The eleven instructional dimensions were first presented at the American Education Research Association (Bernard et al., 2013) and further elaborated at the World Education Research Association (Borokhovski et al., 2015). The authors chose to emphasize the framework's spectrum aspect that classroom instruction is never exclusively S-C or T-C (teacher-centered) but a combination of both. An observation also made by Gersten et al. (2008) in their systematic review that investigated mathematics teaching practices that:

> […] found no examples of studies in which students were teaching themselves or each other without any teacher guidance; nor did [we] find studies in which teachers conveyed […] content directly to students without any attention to their understanding or response […]. (p. 12).

While the merits of the dimensions were already clear, many more questions about S-C and T-C instruction remained. The specifics of the instructional dimensions are described below, as they pertain to the current M-A (Table 1).

Table 1. *Defining T-C and S-C instructional dimensions*

Instructional dimensions	Dimension description
Course design	Degree to which students participate in course design.
Learning objectives	Degree to which students set learning objectives.
Study materials	Degree to which students select/prepare study materials.
Adaptation of materials and activities	Extent to which study materials and learning activities are generic and unmodified or individualized to account for differences in students' interests, abilities, and expectations.
Pacing/flexibility of instruction	Degree to which students are involved in determining the pace and sequence of learning activities.
Anchored instruction	Degree to which the instruction/exercises are authentic and/or anchored in realistic scenarios and real-world problems.
Problem type	Specifies cognitive processes tapped into for successfully solving different problems from well-structured algorithmic tasks to ill-structured problems in need of creative solutions.
Conceptual level	Conceptual level necessary for achieving learning objectives (i.e., memorization, analyses, understanding, explanation, self-regulation).
Teacher's role	Describes the teacher's role in the classroom (from lecturer/authority figure to facilitator/partner).
Peer collaboration	Identifies the extent to which students work collaboratively/cooperatively in groups/teams.
Self and peer assessment	Degree to which students participate in feedback provision and assessment of each other's learning.

Coding scale:
1=Mostly T-C baseline
2=Some S-C qualities present
3=Teacher's and students' contributions to the respective instructional component are relatively balanced
4=S-C qualities are quite salient, possibly surpassing T-S
5=Highest possible levels of student involvement in instructional practices

Research questions

The following questions guided this review:

- Are the effects of educational technology influenced by the pedagogical framework employed (i.e., S-C instruction)?

- Which specific S-C instructional strategies/learning activities better support the use of educational technology for learning?
- What contextual and demographic variables moderate the effects of educational technology on student achievement outcomes?

Method

Definition of terms

- **Educational technology** is defined as "…a broad variety of modalities, tools, and strategies for learning, [*whose*] effectiveness, therefore, depends on how well [*they*] help teachers and students achieve the desired instructional goals" (Ross et al., 2010, p. 19), a definition previously adopted by Schmid et al., (2014) and consistently used since.
- **Teacher and student-centeredness** is not a dichotomous concept of either/or but is best considered on a continuum ranging from an instructional approach that is predominantly under the teacher's control (low student-centeredness) to one that is organized heavily around students' needs, interests, expectations, and involvement (high student-centeredness). Moreover, this balance is determined not by a single quality but by some characteristics of instruction (instructional events). Specifically, a T-C approach stipulates that the teacher sets the learning objectives, plans lessons, utilizes a direct instructional methodology, assigns readings from pre-determined learning material, provides individual guidance, evaluates and grades student performance. This approach can also be described as the traditional instructional model and was previously the norm in teaching. The S-C approach came about later, largely inspired by Dewey's notion of Progressive Education. This approach places student learning at the heart of the educational endeavour, favouring learning that is student-controlled/mediated and overall student engagement. In S-C teaching, the goal is to emphasize the teacher's role as a facilitator rather than as an instructor. Students' involvement in various instructional events does not necessarily overshadow the teacher's role in S-C pedagogy but it is increased substantially compared to T-C educational practices. For more detailed information about contrasting and, thus, a better understanding of the two from the perspectives of their respective critics and proponents, see Tobias & Duffy (2009). Instructional qualities (dimensions) that allow to distinguish S-C and T-S educational practices are listed in Table 1 above.
- **Student achievement outcomes** are a quantifiable assessment of the knowledge acquired through classwork, group work, project work, assignments and formal testing during a given academic time frame, supposedly reflecting the effects of the respective instructional intervention.

Literature Search Method

M-A methodology is well documented in the literature (e.g., Cooper, 2017; Borenstein et al., 2009). Below we briefly reiterate its main elements and procedures, from operationalizing instructional variables through locating, selecting, and reviewing data to key aspects of data analyses and interpretation applied to this study.

After defining the major concepts and stating the research questions (see above), comprehensive literature searches in line with methods outlined in Kugley et al. (2017) were designed to identify relevant primary empirical studies. Adaptive strategies with related descriptors and terms for *technology use* (e.g., technolog*, computer, "web-based") and *teaching methods* (e.g., "teaching method*," "student cent*," "learner cent*," "learner control," constructivi*) targeted individual databases. An extensive set of databases were searched within the field of education (e.g., Australian Education Index, British Education Index, ERIC), related fields (e.g., ABI/Inform Global, PsycINFO, Sociological Abstracts, Social Sciences Abstracts), and interdisciplinary (e.g., Academic Search Complete, Web of Science). International systematic review organization databases were also consulted (e.g., Campbell Collaboration), and citation searching was conducted on the previous review and M-As, supplemented by Google searches for grey literature.

Inclusion/exclusion criteria and review procedure

To be included, primary studies had to meet the following criteria.

- Time frame: Studies were published between 1971 and 2017.
- Research design: Experimental (e.g., randomized control trials) or high-quality quasi-experiments (e.g., rigorous statistical control for group equivalence).
- Context: Experiments conducted in formal educational settings.
- Comparison: Feature two groups of students exposed to different instructional interventions—with/without educational technology.
- Informativeness: Sufficient description of instructional dimensions for both conditions.
- Outcome relevance: Report valid measures of achievement/skills development.
- Data sufficiency: Provide sufficient statistical information for ES extraction.

Studies were first screened at the abstract level, and those meeting inclusion criteria were then reviewed in their entirety. At both stages, two researchers made their independent judgment regarding study inclusion/exclusion and were then compared. Any resulting disagreements were resolved through the research team's joint deliberation. ES extraction and study feature coding followed the same protocol. The PRISMA diagram included below (Figure 1) depicts the study selection process.

Defining experimental/control conditions

In keeping with methods employed by Schmid et al. (2014), this study considered instructional conditions in which educational technology, as defined above, was used – compared to technology-free control conditions. Thus estimating the difference between the use and non-use of educational technology in terms of their respective impact on students' learning success.

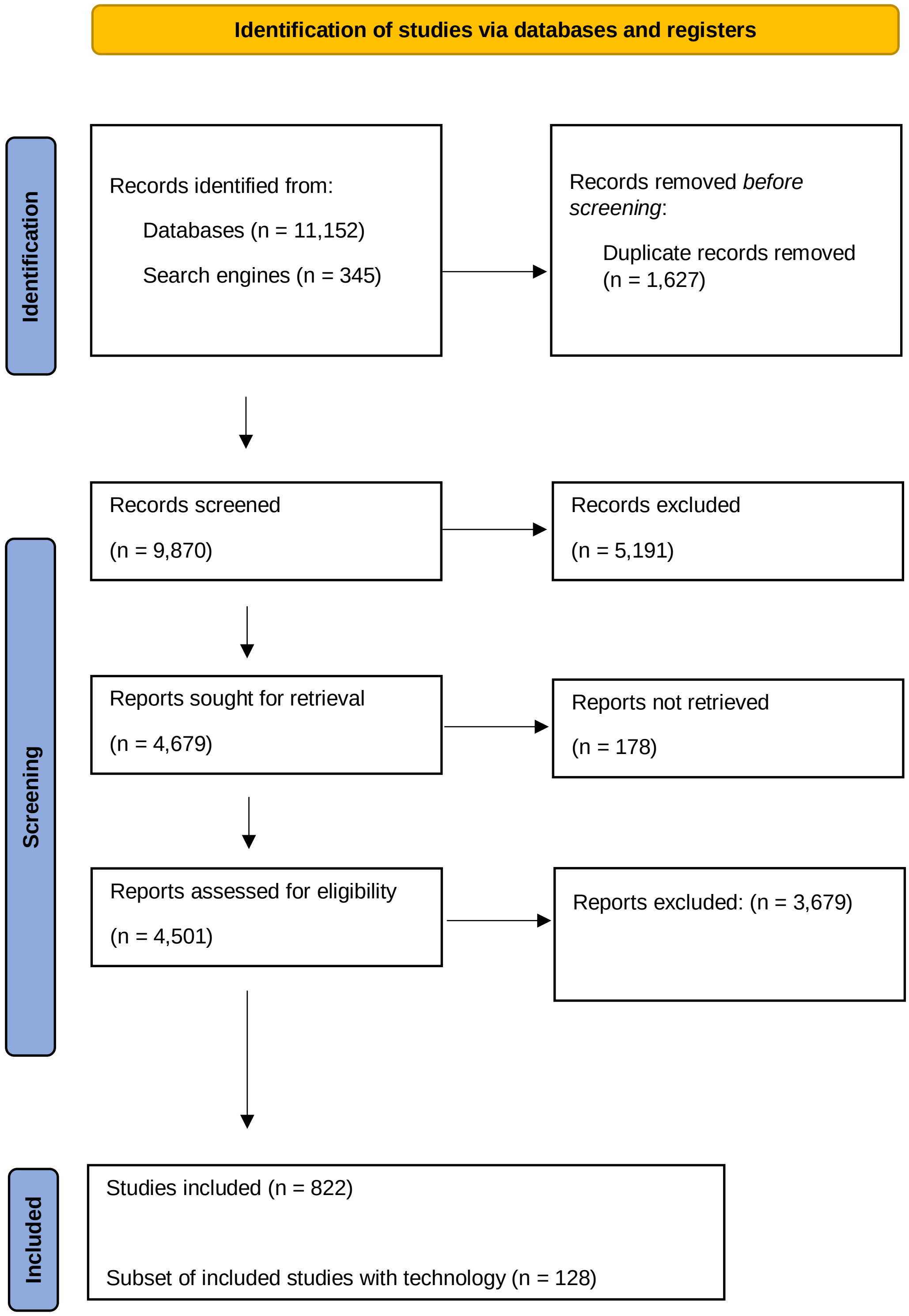

Figure 1. *PRISMA diagram* (Page et al., 2020)

ES calculation/synthesis

The ESs for quantitative intervention studies belong to the *d*-family (i.e., the standardized difference between means of experimental and control conditions, calculated as follows: $d{=}X_E - X_c / SD_{Pooled}$). To correct for potential small sample size bias, *d* was converted to Hedges' *g*. For more details about M-

A statistical and procedural protocol, please refer to Borenstein et al. (2009), Bernard et al. (2014) or Hedges et al. (1989).

The random effects model (Borenstein et al., 2009) was used to aggregate individual *independent* effects into the overall weighted average, and then a mixed model analyzed categorical moderator variables. A method of moments regression analysis was used to analyze continuous predictors. All analyses (including sensitivity and publication bias) were conducted using the *Comprehensive Meta-Analysis* software, version 2.2.057 (Borenstein et al., 2005).

Coding moderator variables

We coded and analyzed moderator variables in the following three categories:

- *Methodological:* Research design, measure source (type, psychometric quality), precision of ES extraction procedure, etc.
- *Contextual/Demographic*: Treatment duration, grade level, subject matter, etc.
- *Instructional/Substantive:* The authors elaborated eleven instructional dimensions (types of instructional events) intended for coding teaching practices on a scale ranging from predominantly T-C to more S-C.

The difference in coding of the above moderators between the experimental (E_T—technology-supported) and control (C_{TF}—technology-free) conditions created a differential score for every instructional dimension that served either as a continuous predictor in regression analysis or allowed for creating groups characterized by various degrees of S-C qualities present to be tested in ANOVA-like moderator variable analyses. For example, if students in the experimental condition worked collaboratively on some group projects/assignments all or most of the time (i.e., coded as '5' or '4' on the peer collaboration dimension), whereas students in the corresponding group worked individually all the time (i.e., coded '1' on the same dimension), resulted in the differential score (subtracting the latter from the former would be '4' or '3'). In such a case, a given experimental group is characterized as featuring S-C instructional quality to a much higher extent than the control group on that dimension: $E_T >> C_{TF}$. Other options ($E_T > C_{TF}$ — differential score of '1' or '2'; $E_T = C_{TF}$ — both groups received an equal code, as well as $E_T < C_{TF}$, $E_T << C_{TF}$ – regardless of whether they were detected or not in the studies reviewed) can be easily deduced across dimensions from this example.

Results

This M-A included 128 studies (involving over 18,200 participants) that were published between 1971 and 2017, specifically related to the use of educational technology. A total of 168 independent ESs were found (in certain cases, several ESs per study), reflecting how the use of educational technology impacts student achievement outcomes. The results are reported below, as they inform the research questions – first and foremost, how an S-C instructional approach influences the overall effect of educational technology use.

Auxiliary analyses

Agreement rates of pair-wise comparisons for decisions throughout all stages of the review (Cohen's kappa) were: κ=0.87 (inclusion decisions); κ=0.74 (coding dimensions); κ=0.85 (ES extraction); and κ=0.82 (coding moderator variables).

Neither significant outliers nor any distortion in the data distribution due to publication bias were found through the respective sensitivity and publication bias analyses. As a result, it was not necessary to make any adjustments to the data. More precisely, a *one-study-removed* analytical routine did not identify any outliers. Recalculated through it, average effects ranged from 0.386 to 0.409 (according to the random effects analytical model). Visual examination of the funnel plot showed a relatively balanced distribution, confirmed by Duval and Tweedie's *trim and fill* routine that suggested no imputation of potentially "missing" studies on either side of the distribution. Also, none of the tested methodological moderators showed significant differences across levels. So, the entire collection of ESs was retained for subsequent core analyses.

The overall effect

The overall effects of using educational technology versus non-use for learning are reported in Table 2, both according to the random effects model and the fixed* effect model, alongside the estimates of the distribution heterogeneity* within the latter.

There are two interesting aspects of this analysis. The first is the rather large random effects average difference between the use and the non-use of technology (g^+). This effect, however, is modified by the large degree of heterogeneity (Q-value and I^2) in the sample, suggesting that a variety of factors relating to instructional conditions or the sample itself may mitigate this average. This led to a further search for sources of difference in effect sizes through an examination of moderator variables.

Table 2. *The overall effect of educational technology use on student achievement outcomes*

Models	*k*	*g*+	*SE*	Lower limit	Upper limit	*z*-value	*p*-value
*Fixed effect	168	0.307	0.02	0.28	0.34	19.95	<0.001
Random effects	168	0.402	0.04	0.32	0.48	10.09	<0.001
*Q_{Total}=1,010.83, p<.001, I^2=83.48.							

The overall weighted average ES (random effects model) was g^+=0.402, statistically significant, z=10.09, p<.001) and robust – i.e., *classic fail-safe* N=20,552, indicating the number of potentially missing null effects required to render the observed effect non-significant.

Moderating effects of instructional dimensions

To address the research question of how S-C instructional qualities affect the impact of educational technology on learning outcomes, both meta-regression and analyses of categorical moderator variables were carried out. A meta-regression with the total differential score (i.e., the difference in the degree of student-centeredness between the experimental and control conditions, as operationalized in the Method section) as a predictor variable revealed that as the overall S-C qualities of instructional practices increase, so does the corresponding effect of educational technology on learning (though this tendency was not statistically significant): b_Y=0.02, p=.088, $Q_{Regression}$=2.91.

Taken individually, the instructional dimensions, sorted by the degree of student-centeredness, had some influence on ESs. The results of analyses based on individual differential scores between the experimental and control groups are summarized in Table 3. As described earlier, the former could be equal to the latter (E_T=C_{TF} – differential score of 0), moderately higher (E_T>C_{TF} – differential scores of 1 or 2), substantially higher (E_T>>C_{TF} – differential scores of 3 or 4), or (in a very limited number of cases) lower ($E_T<C_{TF}$). We turned away from the continuous variable analyses to the group membership ANOVA-like analyses here because, in comparison with the overall differential score across dimensions (with the theoretical range of –44 – +44, i.e., a maximum differential score of 4 times 11 dimensions), the differential scores for individual dimensions could only vary from –4 to +4 (the observed range was even narrower – from –2 to +3). Only statistically significant outcomes are reported.

Table 3. *Mixed effects analysis of the differential scores of student-centeredness by individual instructional dimension*

Levels	*k*	g^+	*SE*	Lower limit	Upper limit	*z*-value
a) Course design*:*						
$E_T=C_{TF}$	161	0.380	0.04	0.30	0.46	9.44**
$E_T>C_{TF}$	7	1.019	0.23	0.28	0.45	8.46**
$Q_{Between}=7.49$, $p=.006$						
b) Pacing/flexibility*:*						
$E_T=C_{TF}$	40	0.663	0.07	0.52	0.81	8.93**
$E_T>C_{TF}$	112	0.351	0.05	0.26	0.44	7.77**
$E_T>>C_{TF}$	14	0.021	0.16	-0.29	0.33	0.13
$Q_{Between}=19.33$, $p<.001$						
c) Problem type:						
$E_T=C_{TF}$	103	0.298	0.05	0.21	0.39	6.37**
$E_T>C_{TF}$	63	0.566	0.07	0.43	0.71	7.90**
$Q_{Between}=9.81$, $p=.002$						
d) Conceptual level:						
$E_T=C_{TF}$	65	0.286	0.06	0.17	0.40	4.94**
$E_T>C_{TF}$	101	0.476	0.05	0.37	0.58	8.77**
$Q_{Between}=5.73$, $p=.017$						
e) Peer collaboration:						
$E_T=C_{TF}$	83	0.290	0.05	0.19	0.39	5.48**
$E_T>C_{TF}$	70	0.501	0.06	0.38	0.63	7.86**
$E_T>>C_{TF}$	11	0.736	0.19	0.36	1.12	3.80**
$Q_{Between}=9.80$, $p=.007$						

*$p<.05$; **$p<.01$; Note: E_T=experimental group (with educational technology); C_{TF}=control group (technology-free, i.e., no educational technology use).

As Table 3 indicates, a higher degree of S-C instruction is typically associated with larger ESs. The only exception is the pacing/flexibility dimension, which resulted in the opposite relationship.

Influence of demographic and contextual moderators

Our last research question relates to the potential influence of demographic/contextual moderator variables on student learning. Analysis of these moderators produced a rather limited number of significant findings (Table 4).

Table 4. *Mixed effects analysis of demographic/contextual moderator variables*

Levels	*k*	g^+	*SE*	Lower limit	Upper limit	*z*-value
a) Grade Level:						
Elementary Students (K-3)	33	0.269	0.06	0.16	0.38	4.80**
Secondary & High School Students (4-12)	46	0.591	0.09	0.41	0.77	6.43**
Undergraduates Students	77	0.328	0.06	0.21	0.45	5.35**
Graduate Students	11	0.518	0.12	0.29	0.75	4.44**
$Q_{Between}$ = 11.03, p = .012						
b) Treatment Duration:						
One Day/One Shot Experiment	25	0.312	0.08	0.16	0.47	3.97**
Up to one Week	14	0.237	0.12	0.00	0.47	1.96*
Between a Week & a Semester	62	0.565	0.08	0.41	0.72	6.96**
One Semester	48	0.404	0.08	0.25	0.55	5.25**
More than a Semester	19	0.175	0.07	0.03	0.32	2.40*
$Q_{Between}$=14.35, p=.006						

*p<.05; **p<.01.

Finally (and somewhat contrary to previous observations by Schmid et al., 2014), there was some significant tendency for ESs to increase over time: b_Y = 0.0101, p=.01, $Q_{Regression}$=7.0.

Discussion

The quantitative synthesis of 168 independent ESs revealed a positive, though not statistically significant, trend when student-centeredness is operationalized as a differential score of cumulated S-C qualities between the experimental (i.e., technology-supported) instructional condition and the control (i.e., technology-free) instructional condition. This overall tendency indicates that educational technology employed in more S-C learning environments has the potential to produce higher achievement outcomes. However, as we argued earlier, the S-C pedagogy is not a unitary construct but rather various combinations of instructional events (or dimensions), each of which may be organized around students' interests, objectives, motivation, learning strategies, etc. to a higher or lower degree (in other words, more or less S-C, as contrasted to a baseline of a more traditional T-C pedagogy) and subsequently exert variable influence on learning. When addressed individually, some of these dimensions produced more pronounced (statistically significant) ESs. Specifically, when technology-supported instructional conditions were also higher or much higher than their control counterparts in the following S-C qualities: course design, problem type, conceptual level, and peer collaboration, the corresponding effects of educational technology use on learning outcomes were positive: g^+=1.02 for E_T>C_{TF} on course design; g^+=0.57 for E_T>C_{TF} on problem type; or g^+=0.74 for E_T>>C_{TF} on peer collaboration. In contrast, on the dimension of pacing/flexibility, the increase (E_T>>C_{TF}) in student-centeredness led to the ES virtually indistinguishable from zero (g^+=0.02), whereas when both conditions are equal in that quality, the average ES was significantly higher (g^+=0.66).

To better understand and hopefully translate these findings into more effective instructional practices, it is important to: (1) reiterate what the key research on the effects of educational technology on academic achievements tells us and (2) illustrate what pedagogical approaches and specific teaching and learning activities may characterize more S-C vs. more T-C qualities of teaching and learning. Below, we attempted to briefly do both.

As already explained above, educational technology is a complex concept to study, with many potentially confounding variables and the exact conditions and reasons why technology is effective in learning have yet to be fully understood. We need to have a better grasp on how learning occurs to better predict how it can be positively and consistently influenced by educational technology. However, benefitting from increasingly sophisticated analysis methodology and the ability to compare large volumes of data, some recent research, including M-As, has gradually begun to focus on the questions that go beyond the simple use of technology compared to the absence of educational technology in education. Studies within this emerging framework gradually replace the yes/no comparisons with more relevant ones that address the question of what value (in terms of learning outcomes) could be added by employing specific pedagogical approaches and instructional design solutions to support/enhance the use of particular educational technology in comparison with the same technology without these supplements (e.g., D'Angelo et al., 2014; Schmid et al., 2014). This new framework broadens our understanding of the most effective conditions and adequate contexts for employing specific technological tools and applications in education. No less important is the ability to distinguish such meaningful (informed by pedagogical theory and sound instructional design) uses of educational technology from those stemming from just general excitement ("hype" – in terms of Gartner's model) about the newest cutting-edge technological tools and applications (Tamim et al., under review).

Consider, as an example, an M-A and case study conducted by Tamim et al. (2015) that summarizes research evidence about tablets and smart mobile device use in K-12 institutions. Large-scale government-supported projects from 11 different countries around the world were investigated, comparing the effects of having and not having tablet-like portable devices in classrooms. The results were as varied as the pedagogical approaches employed. However, ESs were greater when tablets were used by students and teachers alike in some pre-designed coordinated fashion. If the tablets served a specific academic purpose (used for a specific subject with a particular app for accomplishing a specific task, like reviewing vocabulary in second language learning or carrying out a collaborative project rather than for general use across subjects/tasks), students' appreciation of the assistance provided was enhanced as were the corresponding achievement ESs.

Instructional qualities that are S-C, as operationalized here, may enhance, or impede the effects of educational technology on learning. Some examples from the studies included in our M-A about specific instructional practices, categorized under different S-C dimensions, and how these exert educational technology's positive influences are provided below.

Instructional dimensions that enhance the effect of educational technology

Four of the 11 instructional dimensions considered in the review have a significant positive impact on the effectiveness of educational technology use. They are course design, problem type, conceptual level, and peer collaboration. All showed the same tendency to increase the effect of educational technology on student achievement as S-C instruction increases.

The first of these effective dimensions, *course design*, can be described as the extent to which the student is involved in the design of the course or in determining the content being taught. This dimension did not emerge very often in our analysis, as students are not usually invited to have their say in this aspect of instruction. However, there are a few examples of elevated student involvement in course design. In one (Cimerhanzel-Nestlerode & Cooper, 1981), the authors studied the effectiveness of individualized instruction in an intermediate college-level foreign language course at the University of Houston. Students in the experimental condition, contrary to their control counterparts who were taught through a more traditional lecture-recitation instructional approach, participated in selecting study materials and preparing learning activities according to their personal preferences. As a result, they outperformed the control group in reading, oral comprehension and speaking, and demonstrated a better attitude toward Spanish (spoken but not written). The associated overall ES was g=0.68.

The *problem type* dimension relates to the cognitive processes involved in solving different types of problems (on a continuum from well-defined problems with algorithmic solutions to ill-defined problems that require a more creative approach). For example, Jeffries and Maeder (2006) used vignettes, a type of problem-solving approach, in teaching a graduate educational psychology course. Vignettes in the experimental group involved the presentation of a hypothetical educational problem to be analyzed and solved. The first four in-class vignettes were addressed by students working in pairs with occasional instructor feedback, which were then discussed by the whole class, focusing on the detailed analyses of the exemplary responses. The next four vignettes were assigned to students online to be solved individually, each followed up by a specific learning strategy: (a) in-class joint discussion; (b) generic critique from the instructor to the entire class; (c) review of three exemplary responses by the whole class on the online discussion board; and (d) revision of an inaccurate/incomplete response (created by the instructor) to a selected vignette to identify the errors and come up with the correct solution. The authors outline the merits of this methodology to promote in-service and pre-service teachers' understanding and retention of psychology-related content. The added value of scaffolded vignette assessment was compared to four other teaching approaches resulting in an average ES of g=0.64.

The *conceptual level* dimension refers to the cognitive level required to achieve learning objectives (i.e., memorization, analyses, understanding, explanation, self-regulation). Both problem type and conceptual level, in a sense, may be linked to Bloom's taxonomy of educational goals and learning processes. In our review, a good example of this dimension at work is Schneider and Renner's (1980) study. This research takes a more fundamental look at two teaching styles – one the authors refer to as an *exposition* style, the more traditional or formal approach to teaching and the other they call *inquiry* or concrete instruction. This newer methodology is all about experimentation and hands-on learning. The authors sought to compare the two teaching approaches with science learning in 9th graders. Both groups of students were taught the same physical science content (four modules about static electricity, current electricity, light and optics, and sound) for 12 weeks, with a focus on concrete operational thinking for each topic. The only distinguishing factor between the two groups was the method of instruction: exposition vs. inquiry. The inquiry group of students were instructed according to the Science Curriculum Improvement Study, where teachers used oral explanation sessions, motion pictures and film strips, textbooks, questions and problems, supervised study, and demonstration methods of instruction. In the exposition group, reading was the primary instructional approach. The results greatly favoured the inquiry teaching approach, especially for students who tended to favour a concrete operational learning style. Schneider and Renner's findings were some of the first to indicate that an active approach to learning is more beneficial than traditional teaching methods. The resulting ES was g=0.80.

Finally, the *peer collaboration* dimension depicts the extent to which students engage in collaborative practices (e.g., working in teams or groups to accomplish a learning task or a project). The Olgun and Adali (2008) revealed the added value of using a case study teaching approach in teaching 5th-grade students about viruses, bacteria, fungi and protista. Encouraging active collaborative problem-solving as opposed to rote memorization. The case study approach stems from the constructivist movement, presented in the context of international science education reforms. This teaching method consists of fact-based narratives, values, and issues. The experimental group of students received a collaborative case study instructional approach, while the control group was taught in a more traditional fashion (assigned reading and teacher-led instruction). Pre-test/post-test scores and student journal entries informed the results. Not only did the experimental class find the case study approach more engaging and interesting, but their learning of the topic was increased compared to that of the control group, as reflected in the ES of g=1.41.

Conversely, there is one dimension that appears to have a more negative effect on student learning outcomes. Granting students more control over *pacing/flexibility,* tends to minimize the effect of educational technology use. This may reflect the fact that dealing with educational technology at their own pace and according to their own priorities, in addition to managing the progress of their study can overwhelm students' self-regulation skills, most prominently true for certain academic grade levels. However, this assumption would need to be clarified in future research.

As is quite evident from the above examples, the influence of each instructional dimension on learning outcomes is hardly unique. Typically, they work in combinations. For example, the studies by Jeffries and Maeder (2006) and Olgun and Adali (2008) illustrate the effect of not just problem-solving, but also collaborative problem-solving. When it comes to the clarity of individual interpretations, such observations could be perceived as a confounding factor. However, and more importantly, it opens this notion to further research with the potential of identifying the most influential combinations of specific instructional dimensions that determine an effect on learning not individually but jointly – in different contexts and for various categories of students.

Educational technology supports cognition

The observed pattern of results is indicative of the positive influence of learning environments that are more focused on challenging problems (including ill-structured ones that require creative solutions), conceptually complex, and, as such, tap into higher levels of cognitive and meta-cognitive processes, implemented in the context of engaging collaboration among learners. Cognitive tools that function as scaffolding appear to be most beneficial to students with the effect of producing more meaningful learning akin to what Cobb (1997) and Mayer (2008) had in mind in relation to interactive educational technology, as largely supported by more recent research findings (e.g., Schmid et al., 2014; Janssen & Kirschner, 2020; Schneider & Preckel, 2017).

When educational technology weakens learning

It has been found that, in some specific cases, educational technology can have a negative impact on student learning outcomes. When technology use is associated with some sort of "informational overload" and requires more time for mastery (e.g., when the students are left to deal with technology independently), students may be overwhelmed. The student's cognitive load is increased rather than relieved, and the learning outcomes suffer or are not helped. As shown in this M-A, the average effect of educational technology on learning when the former is employed under the conditions of increased flexibility was virtually zero. These pitfalls are better avoided or counteracted, by employing educational technology supported by adequate pedagogical solutions.

Demographic variables

Beyond the instructional dimensions, moderator variable analyses revealed that the effects of educational technology in S-C instructional contexts tend to increase in the higher academic grade levels, both in K-12 and postsecondary education. That is the use of educational technology with middle and high school students resulted in significantly higher effects than in elementary grades (g^{+}=0.59 vs. g^{+}=0.27), and graduate students outperformed undergrads (g^{+}=0.52 vs. g^{+}=0.33). Several factors may contribute to these findings, including student maturity, increased capacity for self-regulation, and better familiarity with the educational system that is acquired over time.

Conclusion

The impact of educational technology on student learning outcomes has been investigated before. This paper adds to the discussion of the merits of S-C instructional environments compared to more traditional T-C teaching approaches. The strength of this M-A, in the authors' opinion, lies in providing extra clarity by operationally defining both approaches as combinations of instructional dimensions that could introduce specific S-C qualities into real educational practices. This framework of instructional dimensions describes the extent to which any given pedagogical approach qualifies as more S-C vs. more T-C instructional environments, thus reducing the potential ambiguity that tends to typically arise when such comparison is made based only on labels. Indeed, it should be emphasized that the classification of S-C and T-C approaches is not to be considered as a simple dichotomy. A healthy dose of both approaches may present the best prospective for learning when the right balance is achieved. The problem, however, is that this hypothetical balance is not universal, but depends on a variety of factors – subject matter related, motivational, contextual, demographic, etc. Discovering, examining, and describing such factors is one of the focal points for future research on the matter. The authors by no means suggest the inferiority of T-C teaching. Rather, their goal is to highlight the merits of some specific aspects of S-C teaching and their potential benefits (but also pitfalls) for student learning when educational technology is employed.

This M-A also serves as an important reminder that the use of educational technology alone simply is not sufficient for optimal learning to occur. Pedagogy and instructional design must be part of the equation. Teachers should be aware that certain subject matters are better taught with certain pedagogical approaches aided by specific educational technology. The same is true for teaching certain groups of learners. The aim is to create more dynamic and interactive learning environments for most students. Pedagogical strategies that are well-designed and user-friendly tend to produce better learning outcomes. Examples in the domain of educational technology often include (but are not limited to) simulations, serious games, wikis etc., as these can offer cognitive support for deep learning, as well as entice active, participative, meaningful learning, engaging both the students and their teachers (e.g., Schwartz & Schmid, 2012). Technology can play an important role in shaping student learning, e.g., by providing access to new realms in teaching that were not possible before, extending the student's learning experiences, but only if guided by sound principles of instructional design, not by fashion or exaggerated expectations. Further research, including comprehensive systematic reviews, should inform educational practice on how technological tools can facilitate and optimize learning by identifying the most cost-effective solutions and properly incorporating relevant pedagogical strategies that account for students' abilities, interests, and learning goals.

References[1]

Bernard, R. M., Abrami, P.C., Lou, Y., Borokhovski, E., Wade, A., Wozney, L. et al. (2004). How does distance education compare to classroom instruction? A meta-analysis of the empirical literature. *Review of Educational Research*, 74(3), 379-439. http://dx.doi.org/10.3102/00346543074003379

Bernard, R. M., Borokhovski, E., & Abrami, P. C. (2013, April). *Teacher-centered and student-centered pedagogy: A meta-analysis of classroom practices and processes* [Paper presentation]. 2013 meeting of the American Educational Research Association, San Francisco, CA.

Bernard, R. M., Borohhovski, E., Schmid, R. F., Tamim, R. M., & Abrami, P. C. (2014). A meta-analysis of blended learning and technology use in higher education: from the general to the applied. *Journal of Computing in Higher Education*, *26*, 87-122. https://doi.org/10.1007/s12528-013-9077-3

Bernard, R. M., Abrami, P. C., Wade, A., Borokhovski, E., Tamim, R., Surkes, M. A., & Bethel, E. C. (2009). A meta-analysis of three interaction treatments in distance education. *Review Of Educational Research*, *79*, 1243-1289. https://doi.org/10.3102/0034654309333844

Borenstein, M., Hedges, L., Higgins, J., Rothstein, H. (2005). *Comprehensive Meta-analysis* Version 2.2.057, Biostat, Englewood NJ.

Borenstein, M., Hedges, L., Higgins, J., Rothstein, H. (2009). *Introduction to meta-analysis.* Chichester, UK: Wiley.

Borokhovski, E., Bernard, R. M., Tamim, R. M., Abrami, P. C., & Schmid, R. F. (2015, August). *Can we measure the comparative effects on learning of the student-centered and teacher-centered pedagogical practices? Preliminary results of a meta-analysis* [Paper presentation]. World Education Research Association 2015 Focal Meeting, Budapest, Hungary.

Borokhovski, E., Tamim, R. & Pickup, D. (2022). Technology Application in Teaching and Learning: Second-Order Review of Meta-Analyses. *Commonwealth of Learning (COL) Canada* http://hdl.handle.net/11599/4069

Cimerhanzel-Nestlerode, S. R. M., & Cooper, J. (1981). *Individualizing instruction in college-level Spanish: A study of student achievement and attitude* [Paper presentation]. Annual Meeting of the Southwest Educational Research Association, Dallas, TX.

Clark, R. E. (1994). Media will never influence learning. *Educational Technology Research and Development, 42*(2), 21-29. https://doi.org/10.1007/BF0229908

Cobb, T. (1997). Cognitive efficiency: toward a revised theory of media. *Educational Technology Research and Development*, 45(4), 21–35. http://dx.doi.org/10.1007/BF02299681

Cooper, H. M. (2017). *Research synthesis and meta-analysis: A step-by-step approach* (5th ed.). SAGE Publications.

D'Angelo, C., Rutstein, D., Harris, C., Bernard, R. M., Borokhovski, E., & Haertel, G. (2014). *Simulations for STEM learning: Systematic review and meta-analysis*. SRI International. https://www.sri.com/wp-content/uploads/pdf/simulations-for-stem-learning-brief.pdf

[1] Of the studies included in the meta-analysis, only those cited in the text were included in the References. The complete list of included studies is available upon request.

Gersten, R., Chard, D., Jayanthi, M., Baker, S., Morphy, P., & Flojo, J. (2008). *Mathematics instruction for students with learning disabilities or difficulty learning mathematics: A synthesis of the intervention research*. Portsmouth, NH: RMC Research Corporation, Center on Instruction.

Gredler, M. E. (2012). Understanding Vygotsky for the classroom: Is it too late? *Educational Psychology Review, 24*(1), 113–131. https://doi.org/10.1007/s10648-011-9183-6

Hannafin, M. J., & Land, S. M. (2000). Technology and Student-Centered Learning in Higher Education: Issues and Practices. *Journal of Computing in Higher Education*, Fall 2000, Vol. 12(1), 3-30.

Hattie, J., Yates, G. C. R. (2014). *Visible Learning and the Science of How We Learn*. Routledge, London and New York. Chapter 21.

Hedges, L. V., Shymansky, J. A., & Woodworth, G. (1989). A practical guide to modern methods of meta-analysis. Washington, DC: National Science Teachers Association.

Issenberg, S. B., McGaghie, W. C., Gordon, D. L., Symes, S., Petrusa, E. R., Hart, I. R., & Harden, R. M. (2002). Effectiveness of a cardiology review course for internal medicine residents using simulation technology and deliberate practice. *Teaching and Learning in Medicine: An International Journal*, 14(4), 223–228. http://dx.doi.org/10.1207/S15328015TLM1404_4

Janssen, J., & Kirschner, P. A. (2020). Applying collaborative cognitive load theory to computer-supported collaborative learning: Towards a research agenda. *Educational Technology Research and Development*, *68*(2), 783-805.

Jeffries, C., & Maeder, D. W. (2006). Using instructional and assessment vignettes to promote recall, recognition, and transfer in educational psychology courses. *Teaching Educational Psychology*, *1*(2), 1-19.

Jonassen, D. H. (2000). Revisiting activity theory as a framework for designing student-centered learning environments. *Theoretical foundations of learning environments*, *89*, 121.

Kozma, R. B. (1991). Learning with media. *Review of Educational Research 61*, 179-211. https://doi.org/10.3102/00346543061002179

Kugley, S., Wade, A., Thomas, J., Mahood, Q., Klint Jørgensen, A.-M., Hammerstrøm, K., & Sathe, N. (2017). Searching for studies: a guide to information retrieval for Campbell systematic reviews. *Campbell Systematic Reviews*, *13*(1), 1-73. https://doi.org/10.4073/cmg.2016.1

Land, S., & Jonassen, D. (Eds.). (2012). *Theoretical foundations of learning environments*. Routledge.

Linden, A., & Fenn, J. (2003). *Understanding Gartner's hype cycles* [Strategic Analysis Report R-20-1971]. Gartner Research

Mäkitalo, K., Weinberger, A., Häkkinen, P., Järvelä, S., & Fischer, F. (2004). Epistemic cooperation scripts in online learning environments: fostering learning by reducing uncertainty in discourse? *Computers in Human Behavior*, *21*, 603–622. http://dx.doi.org/10.1016/j.chb.2004.10.033

Mayer, R. E. (2008). *Learning and instruction* (2nd ed.). Upper Saddle River, NJ: Merrill Prentice-Hall.

O'Donnell, A. M., D'Amico, M., Schmid, R. F., Reeve, J., & Smith, J. K. (2008). *Educational psychology: Reflection for action* (Canadian ed.). Mississauga, ON: John Wiley and Sons Canada.

Olgun, O. S., Adali, B. (2008). Teaching grade 5 life science with a case study approach. *Journal of Elementary Science Education*, *20*, 29-44. https://doi.org/10.1007/BF03174701

Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S.,… Moher, D. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ,*372(71). https://doi.org/10.1136/bmj.n71

Ross, S. M., Morrison, G. R., & Lowther, D. L. (2010). Educational technology research past and present: balancing rigor and relevance to impact school learning. *Contemporary Educational Technology*, *1*, 17–35. https://doi.org/10.30935/cedtech/5959

Schmid, R. F., Bernard, R. M., Borokhovski, E., Tamim, R. M., Abrami, P. C., Surkes, M. A., Wade, C. A., & Woods, J. (2014). The effects of technology use in postsecondary education: A meta-analysis of classroom applications. *Computers & Education*, *72*, 271-291. http://dx.doi.org/10.1016/j.compedu.2013.11.002

Schneider, M., & Preckel, F. (2017). Variables associated with achievement in higher education: A systematic review of meta-analyses. *Psychological bulletin*, *143*(6), 565.

Schneider, L. S., & Renner, J. W. (1980). Concrete and formal training. *Journal of Research in Science Teaching*, *17*, 503-517.

Schwartz, N. H., & Schmid, R. F. (2012). *Using technology to foster a meaningful learning environment*. In M. J. Lawson, & J. R. Kirby (Eds.), The quality of learning: Dispositions, instruction, and mental structures. Cambridge, UK: Cambridge University Press.

Tamim, R. M., Bernard, R. M., Borokhovski, E., Abrami, P. C., & Schmid, R. F. (2011). What forty years of research says about the impact of technology on learning: A second-order meta-analysis and validation study. *Review of Educational Research*, *81*(3), 4-28. http://dx.doi.org/10.3102/0034654310393361

Tamim, R. M., Borokhovski, E., Pickup D., & Bernard, R. M. (2015). Tablets for teaching and learning. A systematic review and meta-analysis. *Commonwealth of Learning (COL).* http://hdl.handle.net/11599/1012

Tamim, R. M., Borokhovksi, E. F., Pickup, D. I., Schmid, R. F., & Bernard, R. M. (Under review). Beyond technology hype: Two complementary meta-analyses and a qualitative systematic review of tablets for teaching and learning. *Review of Educational Research*.

Tobias, S., & Duffy, T. M. (Eds.). (2009). *Constructivist instruction: Success or failure?* Routledge.