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Technology-enhanced creativity: A multiple case study of digital technology-integration expert teachers' beliefs and practices

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ABSTRACT

This multiple case study explored educational technology-integration expert teachers' beliefs about and experiences with nurturing creativity in technology-enhanced learning environments. Data was collected through qualitative methods (interviews, classroom observations, document analysis) from 12 purposefully sampled technology-integration expert secondary school teachers of six curricular areas, and their students. Analysis revealed that expert teachers' epistemic beliefs about creativity influenced their technology-based creativity fostering practices, with beliefs about assessment constituting a considerable barrier. Participants valued and implemented six overarching technology-based creativity-fostering approaches across the curriculum: igniting students' creativity; supporting idea development; creating digital products; scaffolding students' creative processes; augmenting creative collaboration among students; and facilitating the evaluation of creative student outcomes. Within these approaches the study identified several both subject-specific and -general technology-based creativity-fostering strategies of practical relevance providing pointers for future research conducted in secondary school settings. The investigation of practice highlighted that even expert teachers have difficulties with implementing technology-based creativity-fostering instruction within regular curricular timeframes and accomplishing high levels of technology integration. Implication for research, policy, teacher education, and practice are discussed.

1. Introduction

In recent years developing young people's creative competence has evolved to become a key educational goal around the world due to to the associated significant economic, societal, and personal benefits (Beghetto, 2010; Vincent-Lancrin et al., 2019; Wyse & Ferrari, 2014). In addition to creativity, technology is also an important aspect of today's classrooms. Digital technology has been suggested to make a distinctive contribution to fostering students' creativity by providing new tools and environments for learning to be creative and learning through being creative (Glăveanu, Ness, Wasson, & Lubart, 2019; Loveless, 2003, 2007; Lubart, 2005; Mishra, Yadav, & the Deep-Play Research Group, 2013). The view that technology can promote creativity and learning is also shared by educators across many countries (Cachia & Ferrari, 2010).

Findings of both earlier and more recent reviews and meta-analyses show that a relatively small number of studies have investigated the effects of technology-enhanced learning interventions on creativity (Scott, Leritz, & Mumford, 2004; Lai, Yarbro, DiCerbo, &

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deGeest, 2018; Ma, 2006; Scott, Leritz, & Mumford, 2004; Valgeirsdottir & Onarheim, 2017). Empirical evidence on technology-based enhancement suggests that creativity can be increased using digital tools, yet findings of experimental studies appear to have limited relevance for K-12 education (Lai et al., 2018), and thus indicate a need for more research with themes and questions grounded in the realities of classroom practice.

Researchers generally agree that the beliefs teachers hold about creativity shape the ways in which they engage in the promotion of students' creative capacities (Andiliou & Murphy, 2010; Beghetto, 2010; Skiba, Tan, Sternberg, & Grigorenko, 2017). Previous studies have produced valuable findings on how educators conceptualize creativity, their views about the characteristics of creative students and teachers, and perspectives on the features of creativity-conducive learning environments (Andiliou & Murphy, 2010; Bereczki & Kárpáti, 2018; Mullet, Willerson, Lamb, & Kettler, 2016). Belief studies suggest that highly-accomplished teachers may conceptualize creativity consistent with the literature, exhibit a rich repertoire of creativity-fostering teaching strategies, and can, therefore, play a fundamental role in promoting research-grounded views and practices among educational stakeholders (Henriksen & Mishra, 2015; Merriman, 2015; Scott, 2015). However, highly accomplished technology-integrator educators' views on creativity, technology, and learning, to our knowledge, have not yet been explored.

Finally, insights in teachers' beliefs and practices have been gained through both subject-specific and cross-disciplinary investigations in the area of creativity (Andiliou & Murphy, 2010; Bereczki & Kárpáti, 2018; Mullet et al., 2016), and technology integration (Ertmer, Ottenbreit-Leftwich, & Tondeur, 2015; Tondeur, Van Braak, Ertmer, & Ottenbreit-Leftwich, 2017) separately. The study presented here aims to reveal how technology-enhanced creativity is conceptualized and promoted within the core curricular areas and across them to refine the body of knowledge on teachers' beliefs about creativity and its technology-supported promotion.

The purpose of the study was then to explore educational technology-integration expert teachers' beliefs about and experiences with nurturing creativity in technology-enhanced learning environments across six areas of the secondary school curriculum (EFL, Hungarian language and literature, mathematics, science, social studies, and visual arts) to identify research themes and questions grounded in the realities of the classroom, as well as to support policy, teacher education, and practice in the area of technology-enhanced creativity education.

The study was designed to answer the following research questions:

Q1: What characterizes technology-integration expert secondary school teachers' epistemic beliefs about creativity?

Q2: What characterizes technology-integration expert secondary school teachers' beliefs about nurturing creativity with technology in their subject areas?

Q3: What characterizes technology-integration expert school teachers' enactment of their beliefs about nurturing creativity with technology in the classroom?

Our study also provides insights into the barriers and enablers teachers perceive when fostering creativity, the results of which are presented in a different paper.

2. Literature review

2.1. Understanding creativity in education

Creativity is widely defined as an individual or group process that involves the production of outcomes that are deemed both novel/original and useful/appropriate in a specific social context, and is influenced by a number of personal and environmental factors (Amabile, 1996; Csíkszentmihalyi, 1996; Plucker, Beghetto, & Dow, 2004; Stein, 1953; Sternberg & Lubart, 1992). Novelty/originality and usefulness/appropriateness as joint requirements for creativity are largely dependent on the level of creative expression in focus (Beghetto & Kaufman, 2007). Education is more concerned with the initial levels of creative achievement, namely little-c creativity (i.e. student contributions that are original and valued in the context of the classroom), and mini-c creativity (i.e. students' personally novel and meaningful ideas, products), since these are the forms that can be generally be promoted in school settings (Beghetto & Kaufman, 2007).

By definition, creativity is relevant to any domain (Runco, 1999), while the domains provide the context within which people can be creative (Craft, 2005). In addition, creativity in any domain requires both generalized and domain-specific creative skills and abilities (Baer & Kaufman, 2005; Lubart & Guignard, 2004; Plucker & Beghetto, 2004). Being partly domain-specific, creativity should be conceptualised, nurtured, and assessed within the context of each curricular area rather than perceived as an independent generic skill (Baer, 1998). Yet, given the multidimensional nature of the construct, enhancement should take into account both the general and specific aspects (Barbot, Besançon, & Lubart, 2016).

Researchers generally conceptualize and investigate creativity along one or more of its four Ps: creative person, process, product, and place (Rhodes, 1961). More recent models include all four Ps hypothesizing that creativity occurs if the above components converge (Amabile, 1996; Csíkszentmihalyi, 1996; Sternberg & Lubart, 1992). Confluence views, thus suggest that students' creative development in the classroom will result from the convergence of their personal factors, including characteristics, knowledge, skills, dispositions, and the physical, social and pedagogical environment surrounding them (Cropley, 2011).

2.2. Fostering creativity in education

Research has demonstrated that people's creativity can be increased and identified several conditions that influence creative growth. Intervention studies showed that creativity can be enhanced from kindergarten to adulthood both in academic settings and beyond, but there are no agreed-on formulas or set of instructions that guarantee success (2004b, Lai et al., 2018; Ma, 2006; Scott et al., 2004a; Valgeirsdottir & Onarheim, 2017). Enhancement seems most effective when it is systematic, targets domain-specific cognitive skills, includes opportunities to develop creative attitudes and behaviours, and involves realistic tasks and practice, as well as collaboration with peers.

Literature on the environmental conditions conducive to creativity indicate that certain features of the learning environment affect students' creativity, namely the physical (flexible use of space, flexibility and free movement, availability of diverse tools, materials, and technology), the pedagogical (original and exciting learning activities, authentic and realistic tasks, playful approaches, ensuring time for ideas, allowing students ownership of their learning), the psychosocial (trust, mutual respect, collaboration), and the external (collaboration with outside agencies) (Davies et al., 2013).

2.3. The potential of digital technology to support creativity

The use of digital technology to support creativity and learning have been theorized in a range of published work (Glăveanu et al., 2019; Loveless, 2003, 2007; Lubart, 2005; Mishra et al., 2013). For example, Loveless (2003, 2007) argues that creativity-focused activities with new technologies emerge from the interaction of the features of digital technologies, learners' capabilities to express elements of higher-order thinking with technology, and creative processes (using imagination, fashioning, pursuing purpose, being original, judging value). Technology-enhanced creative activities identified by Loveless include developing ideas, making connections, creating and making, collaboration, and the communication and evaluation of creative outcomes with technology.

Other researchers view the role of digital technology in supporting creativity in relation to human-computer interaction (Glăveanu et al., 2019; Lubart, 2005). Glăveanu et al. (2019) and Lubart (2005) proposed four social roles that computers may potentially assume during creative work: 'computer as nanny' (i.e. the capacity of technology to facilitate the management of the creative process by providing a supportive environment and access to a creative mindset), 'computer as pen-pal' (i.e. technology may also facilitate the act of communication and collaboration during the creative process, thus allowing learners to share viewpoints which may potentially lead to gaining more creative insights), 'computer as coach' (i.e. computers as expert systems may be used to enhance students' creativity by providing tutorials and exercises that further creativity-relevant cognitive processes, strategies and techniques.), and 'computer as colleague' (i.e. computers may work in partnership with learners in the creative process by actively contributing to the idea generation, evaluation, and refinement).

2.4. Research on technology-based creativity enhancement

Though the link between creativity and technology is often cited in education, earlier literature reviews and meta-analyses suggest that only a small number of studies have investigated the effects of technology-enhanced learning interventions on creativity (Lai et al., 2018; Ma, 2006; Scott et al., 2004a, 2004b; Valgeirsdottir & Onarheim, 2017).

Our review of technology-enhanced creativity interventions emanating from the past 15 years[1] identified through the keyword-searching of creativity[2] and educational technology[3] focused journals and their reference-list checking has provided further evidence that certain uses of digital tools can promote creativity. Findings of controlled experimental and quasi-experimental studies with technology-supported instruction as a treatment condition and creativity as a dependent variable revealed six types of effective technology-based creativity-enhancement approaches, as presented below.

2.4.1. Technology-based creative thinking and problem-solving training

Research suggest that computer-based creative thinking training can as successfully enhance domain-general divergent thinking abilities as traditional training in young adults (Benedek, Fink, & Neubauer, 2006). Domain-specific technology-based creative problem solving programs applied in technology (Chang, 2013), and physics (Kao, Chiang, & Sun, 2017) have been found to substantially increase K-12 students creative abilities over traditional instruction, while web-based creative problem-solving training in the area of digital citizenship had a positive effect on university students' creativity skills (Kuo, Chen, & Hwang, 2014).

2.4.2. Digital game-based creativity enhancement

Gamified electronic learning environments, and certain serious and commercial video games may also contribute to increased creativity. Technology-based role playing targeting elementary students' creative competences in Mandarin, mathematics, social studies, and English (Chen, Chang, & Wu, 2020) as well as playing an electronic business role play game in an undergraduate management course (Yang, 2015) lead to an increase in participants' divergent thinking skills. Using a digital game-based problem-solving game in the elementary science class has been found to facilitate students' flow experience and promote their self-perceived divergent thinking skills (Hsiao, Chang, Lin, & Hu, 2014). In addition, there is some evidence in the literature reviewed that certain electronic games might increase players' creativity. Playing *Portal 2* (Gallagher & Grimm, 2018), for example, had positive effects on female undergraduates STEM related knowledge, attitudes and divergent thinking skills, while the free gameplay of *Minecraft* (Blanco--Herrera, Gentile, & Rokkum, 2019) increased undergraduate students' general divergent thinking abilities.

[1] January, 2006-June, 2020.

[2] Creativity Research Journal, Journal of Creative Behavior, Thinking Skills and Creativity.

[3] British Journal of Educational Technology, Computers & Education, Educational Technology Research and Development, Journal of Computer Assisted Learning, Journal of Research on Technology and Education.

2.4.3. VR-based creativity enhancement

Recent research highlights the distinctive role VR environments may have in enhancing and expanding creativity by allowing users to experience creativity-stimulating conditions. Specifically, using creative avatars (Guegan, Buisine, Mantelet, Maranzana, & Segonds, 2016), creativity-stimulating virtual environments (Bourgeois-Bougrine, Richard, Burkhardt, Frantz, & Lubart, 2020; Fleury et al., 2020; Guegan, Nelson, & Lubart, 2017), and offering users unusual experiences and opportunities to examine problems from new perspectives (Huang, Hwang, & Chang, 2019; Ritter et al., 2012; Yang et al., 2018) were found to enhance creativity mostly in undergraduate samples.

2.4.4. Stimulating creativity through technology-based communication and collaboration

Some studies suggest that electronic collaboration and communication may positively affect creativity. For example, team collaboration and competition in electronic environments has increased middle school students' creative performance in design (Chen & Chiu, 2016), while online collaboration has been shown to have similar positive effects on students' creative performance as face-to-face collaboration in an undergraduate nanotechnology course (Usher & Barak, 2019).

2.4.5. Increasing subject-specific creative performance through digital creation

Studies on the effects of creating with digital tools on students' creativity revealed that applying 3D design tools increased high school students' (Chang, 2014; Chang, Chen, Chuang, & Chou, 2019) and collage students' (Yeh, Rega, & Chen, 2019) creative performance in design and engineering. Using electronic mind-mapping lead to more creative photo stories among education undergraduate students (Simper, Reeve, & Kirby, 2016) and more creative tourism brochures produced by EFL undergraduates (Fu, Lin, Hwang, & Zhang, 2019). Multimedia scaffolding proved beneficial for elementary students' electronic painting (Ho, Lin, Chen, & Lee, 2017) and mechanical engineering undergraduates' design creative performance (Kassim, Nicholas, & Ng, 2014).

Literature provides further, yet weaker evidence on technology-enhanced creativity through single group studies. These highlight the benefits of computer-based creative thinking training (Robbins & Kegley, 2010), mobile games (Atwood-Blaine, Rule, & Walker, 2019), electronic collaboration and communication (Rodríguez, Díez, Pérez, Baños, & Carrió, 2019; Stolaki & Economides, 2018; Yeh et al., 2012), and technology-enabled creation (Chong & Lee, 2012; Hu, Yeh, & Chen, 2020; Noh & Lee, 2020; Saorín et al., 2017) on participating students' creative abilities.

2.5. Teachers' beliefs about technology-enhanced creativity

Teachers' epistemic beliefs about creativity shape the ways in which they promote students' creative capacities in the classroom (Andiliou & Murphy, 2010; Skiba et al., 2017). Systematic reviews have pointed out that these beliefs are often at variance with the scientific theories of creativity (Andiliou & Murphy, 2010; Bereczki & Kárpáti, 2018; Mullet et al., 2016). Though teachers generally value creativity, they often believe that it means originality but not appropriateness, is relevant for the arts, cannot be nurtured in every student, and cannot be assessed. Studies have also shown that teachers' creativity beliefs are context dependent (e.g. Gralewski, 2016; Katz-Buonincontro et al., 2020), with certain samples holding creativity-related pedagogical beliefs which are more aligned with research (Bereczki & Kárpáti, 2018). Especially highly-accomplished teachers' views were found to be in line with the literature (Henriksen & Mishra, 2015; Merriman, 2015; Scott, 2015).

Studies investigating teachers' beliefs about fostering creativity with technology have shown that teachers may adopt various stances toward the role of technology in promoting creativity, which is viewed as an enabler (Alsahou, 2015; Cachia & Ferrari, 2010) or as a barrier (Scott, 2015), or both as an enabler of and barrier to students' creative development (Adams, 2013). Fewer studies explored teachers' beliefs in-depth. In these studies, technology was argued to support idea development as well as to increase students' curiosity and interest necessary for creativity in the classroom (Adams, 2013; Alsahou, 2015). Negative effects of technology on creativity reported by teachers included disruption, and the suppression of thinking by access to ready-made answers (Adams, 2013; Scott, 2015).

3. Methods

A qualitative exploratory multiple case study approach has been chosen to examine educational technology-integration expert teachers' beliefs about and experience with nurturing creativity with technology across the secondary school curriculum (Yin, 2014). A case study approach underpinned by qualitative methodology is particularly applicable to the study of teachers' beliefs and practices (Olafson, Grandy, & Owens, 2015). In this study, a case was defined as one technology-integration expert teacher's technology-enhanced creativity-fostering beliefs, and their enactment. The research was collective, since it replicated the research condition across multiple cases, allowing the construction of contextualized experiences and systematic analysis procedures (Baxter & Jack, 2008; Yin, 2014).

3.1. Case selection and sample

Participant teachers able to provide expert opinion on the use of technology to promote student creativity across the secondary school curriculum were selected using a purposeful sampling strategy, more precisely through a combination of criterion, stratified, and maximum variation sampling (Mertens, 2010; Patton, 2002). The predefined selection criteria as well as the reasons for their application are detailed in the following Table 1.

Table 1
Sample selection criteria and reasons.

Selection criteria	Reasons
Must have been teaching at secondary school level.	Less emphasis has been given to teachers' beliefs and practices of nurturing creativity in the secondary school context (Andiliou & Murphy, 2010; Bereczki & Kárpáti, 2018; Mullet et al., 2016).
Must have been working as teachers for at least 5 years.	Research suggests that teachers' effectiveness increases with experience (Kini & Podolsky, 2016). The study aimed to explore expert opinions on creativity and technology, therefore the sample aimed to comprise experienced teachers.
Must have been teaching the following curricular areas: EFL, Hungarian language and literature, mathematics, science, social science, and visual arts.	Given that (1) previous studies of teachers' beliefs and practices of both fostering creativity and of technology integration revealed several subject-specific and subject-general themes, (2) experimental evidence focused on limited age groups and areas of the curriculum, and (3) few studies have explored teachers' beliefs and practices of technology-integrated creativity fostering in depth, we decided to include teachers of various subjects to gain a more complex understanding of the phenomena highlighting both commonalities and differences across the curriculum. Thus, we focused on five core curricular areas: language and literature, mathematics, science, history and a foreign language. Art education has been chosen for its special connection with creativity.
Must have been recognized by other educational technology stakeholders (i.e. governmental and non-governmental educational technology organizations, Hungarian educational technology researchers) as technology-integration experts based on either of the following performance criteria: (1) *have earned a local, regional, state, or national award for teaching with technology,* (2) *have presented at local, regional, state, or national conferences on the topic, and/or have mentored younger teachers or teacher candidates on the topic,* (3) *have earned awards or grant funds related to digital pedagogy,* (4) *have received praise and positive feedback from parents, students, and colleagues for their technology-integrated teaching practice.*	The purposeful selection of participants focused on teachers who excelled in the use of technology for teaching and learning, and could, therefore, provide meaningful insights in nurturing creativity with technology in the classroom for both research and practice.

Potential participants identified through criterion sampling were divided into six subgroups based on their main subject areas. Teachers were then selected from these six strata by including two participants from each subject area in the final sample. We also strived to include cases to maximize variation within the sample based on participants' backgrounds, such as school type, school location, age, gender, and teaching experience.

The sampling strategy adopted yielded the identification of 12 Hungarian technology-integration expert secondary school teachers to participate in the study. The sample size was in accordance with what the literature views as appropriate for a multiple case study approach, since the benefits of such approach might be limited when fewer than 4 cases are chosen or more than 15 (Stake, 2006). The characteristics of the sample are presented in Table 2.

3.2. Data collection: instruments and procedures

Data for this study have been derived from three different methods of data collection: semi-structured interviews (pre- and post-observation), classroom observation, and document analysis. Data were collected over a period of four months in 2017. Each data collection method was guided by a separate protocol to ensure that the ethical and methodological principles were met (see Supplements A–C).

3.2.1. Interviews

In total, 24 interviews were conducted with teachers following the Pre- and Post-Observation Interview Protocols (Supplements A and C). Interview questions were developed based on the main themes identified in the literature on teachers' beliefs about creativity and its nurture (Andiliou & Murphy, 2010; Bereczki & Kárpáti, 2018; Mullet et al., 2016), as well as on the qualitative research instruments designed to explore teachers' beliefs and practices of nurturing creativity (Adams, 2013; Alsahou, 2015; Henriksen & Mishra, 2015; Merriman, 2015; Scott, 2015; Tanggaard, 2011)

Questions of the pre-observation interview focused on how and why teachers were going to use technology to promote creativity in the lesson to-be-observed. Post-observation interviews explored participants' pedagogical beliefs of creativity and its nurture, with special emphasis on the role of technology in fostering students' creative capacities within their specific curricular area. Pre-observation interviews lasted on average 18 min, while the post-observation interviews took on average 60 min. Interviews were conducted face-to-face in teachers' schools.

3.2.2. Classroom observations

To verify and complement data emanating from individual teacher interviews eleven classroom observations were conducted by the first author using the Classroom Observation Protocol (see Supplement B). Teachers were asked to teach a 45−90- minute class period in which they integrated educational technology with the specific goal of stimulating students' creativity, at a time they deemed most convenient based on the curriculum they taught and their timetables. Observation data collected this way were aimed to minimize interference with participants' daily teaching activities, while their choices regarding the student group, the learning environments, the exact length of the instruction, the lesson topic, teaching materials, methods, and technologies applied offered further insights in how they would and could promote students' creativity with technology in their own contexts. An overview of the observed classes is provided in Appendix A.

During the observations detailed notes were taken using the Classroom Observation Sheet developed based on Alsahou (2015) (see Supplement B), and focusing on the overall context of the lesson, on what is happening in terms of teacher and student actions and interaction, as well as on the characteristics of the physical and psychosocial environment. In addition, structured observation data were collected through the Support for Creativity in the Learning Environment classroom observation tool (SCALE, Richardson & Mishra, 2018). SCALE consists of 14 items measuring the environment for creativity in the classroom in three dimensions: Physical Environment; Learning Climate; and Learner Engagement. Items in the Physical environment dimension are related to the available resources and spatial qualities of the learning environment (e.g. "A variety of resources/supplies are available and accessible for students."). Items in the Learning Climate focus on the relationship among teacher and students, and the overall creativity-supporting atmosphere (e.g. "The teacher is a facilitator, co-learner, explorer, or enquirer with students"). Learner Engagement includes the tasks that support students' creativity (e.g. "Students are involved in activities that are open-ended and/or involve choice.") Each item is measured with a 4 point Likert scale (0 – no evidence; 1 – minimal evidence; 2 – moderate evidence; 3 – high evidence). The item "The students are caring, respectful, and value differences" was omitted since this could not be determined consistently for all the observed lesson.

3.2.3. Documents

Finally, 16 documents were collected from teachers including lesson and unit plans, project plans and descriptions, and student artefacts considered by participants to be illustrative of their experience of nurturing creativity in technology-enhanced learning environments. General information about the documents collected from each participant are detailed in Appendix B.

Instruments were piloted with one expert teacher whose data were not included in the study. The pilot study contributed to revising instruments and addressing possible difficulties in the data collection process. For example, the teacher participating in the study highlighted some ambiguous questions which were modified in terms of meaning and wording.

3.3. Data analysis

Data were analysed using a constant comparison method (Strauss & Corbin, 1998). Data were also analysed and organised based on the techniques of within-case and cross-case analysis (Baxter & Jack, 2008; Stake, 2006; Yin, 2014).

3.3.1. Data preparation

Individual interviews conducted with participants were transcribed verbatim, handwritten notes were turned into word processing documents, and paper documents were scanned. All electronic qualitative data files prepared were imported into Atlas.ti 8.3.1 for Mac for further analysis. At the quantitative level, data were prepared to be analysed in MS Excel.

3.3.2. Coding

To address the research questions posed by this study we applied a combination of *inductive* and *deductive coding*.

To explore teachers beliefs about creativity and its nurture, and their technology-based creativity-fostering practice, we used *inductive coding* informed by the framework and procedures proposed by Miles, Huberman, and Saldaña (2014). Inductive coding involved two major cycles, namely first-cycle (initial coding) and second-cycle (pattern coding). First, the two authors read the qualitative data from all but one participant (Judith), and developed initial codes and categories individually. These were then discussed, compared, and refined until final agreement was reached. The first author then coded all data, which was verified by the second author, and discussed until perfect agreement was reached. Finally, a third researcher coded data emanating from one participant (Judith). Meanings and interpretations were also discussed with participants. For the final categories and codes established see Appendices C and D.

To examine the ways in which teachers enacted their beliefs about creativity and its technology-based fostering, we used *deductive coding* methods (Miles et al., 2014). First, the support for creativity in the learning environment was determined through SCALE (Richardson & Mishra, 2018) by the first author who conducted the classroom observations. Second, as we worked to make sense of the nature of creativity-fostering technology-based practice, we realized the relevance of the framework developed by Hughes, Thomas, and Scharber (2006) to assess the extent to which teachers' technology integration improved their practice. Their framework components of Replacement, Amplification, and Transformation (RAT) represent important distinctions pertinent to the implementation of a variety of technology-based pedagogical practices (e.g. Hsieh & Tsai, 2017; Van Zoest, Stockero, & Kratky, 2010), including that of fostering creativity with technology.

Technology-based creativity fostering approaches used in the observed lessons were then categorized as: (1) *Replacement*: technology replaced traditional tools, which did not change creativity-relevant instructional methods, student learning process, or curricular goals; (2) *Amplification*: technology amplified creativity-fostering practices by increasing efficiency or productivity, but practices remained the same; (3) *Transformation*: technology transformed creativity-fostering instruction by introducing entirely new and effective instructional methods, student learning process, or new curricular goals. Deductive coding was carried out by the two authors independently, who reached perfect agreement.

Finally, since the *creativity-fostering potential* (CFP) of teachers' practice seemed to be dependent on the support for creativity in the learning environment as well as on the level of technology integration, a general CFP for the observed lessons and practice described in the documents was established taking into account both aspects. Thus, the two authors independently rated the CFP of the observed lessons and the pedagogical practice described in the documents as *high, medium,* or *modest*. Independent ratings showed perfect agreement.

3.3.3. Data display

The study used two of the data display approaches proposed by Miles et al. (2014): matrix displays in the form of charts and tables allowed us to organize the material into an at-a-glance format for reflection, verification, and drawing conclusions; narrative descriptions in turn provide a prosaic representation and presentation of findings.

3.4. Trustworthiness

This study adhered to the standards of trustworthiness in qualitative research (Lincoln & Guba, 1985) as established by the criteria of credibility, transferability, dependability, conformability.

First, credibility was assured through several methods: *methods triangulation* (Denzin, 1978) was used to check the congruence of findings across data collected through individual teacher interviews, classroom observations, and document analysis; *member checks* (Lincoln & Guba, 1985) were incorporated at different points of the analysis process (interview transcripts and classroom observation summaries were sent to participants for inspection at the beginning of the analysis, and we asked participants for clarifications, as well as discussing interpretations with them throughout the process of meaning-making); *referential adequacy* (Lincoln & Guba, 1985) was examined by archiving one data from one participant (Judith), and analysing it subsequently to test the congruence of findings drawn from the rest of the data; we used extensive *peer briefs* (Lincoln & Guba, 1985) during which the two authors discussed the coding, analysis, and interpretation; in the deductive coding phase, credibility was ensured through *interrater reliability*. Second, to achieve transferability, we sought to provide a *thick description* of the context of investigation (Geertz, 1973), thus allowing the reader to determine the degree of similarity between the present study's sites and the receiving ones. Third, to ensure dependability, we provide a *detailed description of the research process*. Finally, conformability has been achieved through *peer debriefing*. The researchers asked another educational researcher with a PhD to code and analyse data from one participant (Judith). The comparison and discussion of the individual results revealed similar codes and interpretations.

3.5. Ethical concerns

Throughout the study great care has been taken to avoid any harm to participant teachers and students. The two most important ethical aspects considered for this study were acquiring informed consent, and securing confidentiality.

4. Results

To investigate teachers' beliefs about fostering creativity with the technology and their enactment interviews, classroom observations, and document analysis were conducted with 12 technology-integration expert teachers from Hungary. The result section presents what teachers in the study believe about creativity, their views on fostering students' creative capacities through technology, as well as the relationship between their espoused beliefs and enacted practices. Focuses of the investigation along with data sources used are presented in the following Table 3.

4.1. Teachers' epistemic beliefs about creativity

Teachers in this study discussed a range of beliefs they held about creativity. Key beliefs identified from the interview data fell into three categories: teachers' interpretations of creativity (Definitions); what teachers think of the relationship of creativity with school subjects (Specificity); and what teachers believe about the nature of creative potential and its measurement (Malleability). For a thematic map of teachers' beliefs about the nature of creativity see Fig. 1. The complete coding analysis is provided in Appendix C.

4.1.1. Definitions of creativity

The analysis of interviews showed that teachers conceptualized creativity through addressing its chief components: process, product, person, and environment.

Creativity means originality and appropriateness. In addition to defining creativity as as something new, interesting, different, unique, all teachers recognized appropriateness as a joint requirement. Ada, for example, stated that: "Creativity happens when somebody overcomes schematic thinking and produces something new and personal", arguing at the same time that the creative process involves the "production of multiple correct answers, and there is not only one good way of solving a problem".

Creativity requires curiosity, knowledge, hard work, risk-taking, intrinsic motivation, and imagination. As for the personal characteristics necessary for creativity, most teachers (9) mentioned curiosity, interest, and passion. Albert, for instance stated that "there is no creativity without curiosity", and that "curiosity drives creativity". Three other characteristics deemed important for creativity were knowledge (7), commitment and hard work (7), and willingness to take risks (7). The importance of commitment and hard work in the creative process was explained by Albert as follows: "creativity requires interest, perseverance, knowledge, and it is absolutely

Table 2
Sample characteristics.

Pseudonym	School	School type	School location	Subject taught	Age	Teaching experience	Academic background	Post-graduate professional examination	Awards received
Anita (EFL1)	A	general lower- and upper-secondary	Urban	EFL	33	11 years	MA Degree	no	Teacher of the year (school level)
Susan (EFL2)	B	secondary vocational	Urban	EFL	52	26 years	MA Degree	Educational Leadership	Award-winning digital pedagogy projects (international level) Best project award (school level) Instructor of the year (school level)
Boris (SOC1)	C	secondary vocational	Urban	Social science	29	5 years	MA Degree	no	Digital pedagogy project of the year (national level) Individual digital pedagogy award (national level) Digital pedagogy team award (national level)
Elisabeth (SOC2)	D	general lower- and upper-secondary	Urban	Social science	49	24 years	MA Degree	no	none
Judith (HUN1)	E	vocational	Urban	Hungarian language and literature	59	36 years	MA Degree	Digital pedagogy	Digital pedagogy project award (national level)
Martha (HUN2)	F	vocational	Urban	Hungarian language and literature	48	22 years	MA Degree	no	Digital pedagogy project award (1 at national level, 2 at international level) Pedagogical innovation award (national level)
Bill (MAT1)	G	general lower- and upper-secondary	Urban	Maths	37	12 years	MSc Degree	no	Digital pedagogy project award (national and international levels)
Rose (MAT2)	H	secondary vocational	Urban	Maths	50	27 years	MSc Degree	Educational Leadership	Digital pedagogy project award (national level) Good practice featured on national digital pedagogy online repository
Ada (SCI1)	F	secondary vocational	Urban	Science	50	24 years	MSc Degree	Mentor teacher	Digital pedagogy project awards (7 at national and 4 at international level)
Albert (SCI2)	I	general lower- and upper-secondary / vocational	suburban	Science	51	27 years	MSc Degree	Educational Leadership	Digital pedagogy project award (national level) Innovation in education award (regional)
Robert (ART1)	J	general lower- and upper-secondary	Urban	Visual Arts	36	15 years	MA Degree	Educational Leadership	Best practice in gifted education and talent development awards (3 at national level) Teacher of the year (national level)
Zoey (ART2)	K	general lower- and upper-secondary / vocational	suburban	Visual Arts	45	20 years	MA Degree	General	Digital pedagogy award (national level)

Table 3
An overview of the investigation focus along with the data sources used.

Focus of investigation	Data sources		
	Interviews	*Observation*	*Documents*
Teachers' epistemic beliefs about creativity	*X*		
Teachers' pedagogical beliefs about fostering creativity with technology	*X*		
Teachers' enacted beliefs of nurturing creativity with technology	*X*	*X*	*X*

important to help students develop those skills". Finally, intrinsic motivation (5) and imagination (4) were also cited as necessary for creativity in the classroom.

Creativity requires idea time, safety and trust, balance between freedom and constraints. The most widely cited environmental condition for creativity in the classroom was idea time (11). Boris, for example, explained that "in a creativity-stimulating environment, time to discuss ideas is essential". Another recurrent environmental characteristic reported by nine teachers was freedom. In addition, six participants highlighted that freedom and constraints should be balanced in a creative environment. Freedom and constrains were discussed in relation to task requirements as well as referring to the choices students are offered in their learning. Finally, safety and relationships based on trust and mutual respect were also viewed as important elements mentioned by six teachers.

4.1.2. *Specificity*

Participants were also prompted to express their beliefs about the relationship of creativity with the school subjects they taught. Three themes emerged from the analysis.

Creativity is easy to find in the arts, but relevant to all subject areas. Half of the teachers (6), in this study viewed arts as an area in which creativity could easily and naturally manifest, yet all expressed the belief that creativity can be applied to every subject of the secondary curriculum. Anita, for example, commented that "when you hear the word creativity, you first think of artistic creation, but I believe creativity is not only in the arts".

Creativity is specific to each curricular area. Teachers argued that different curricular areas required different forms of creativity,

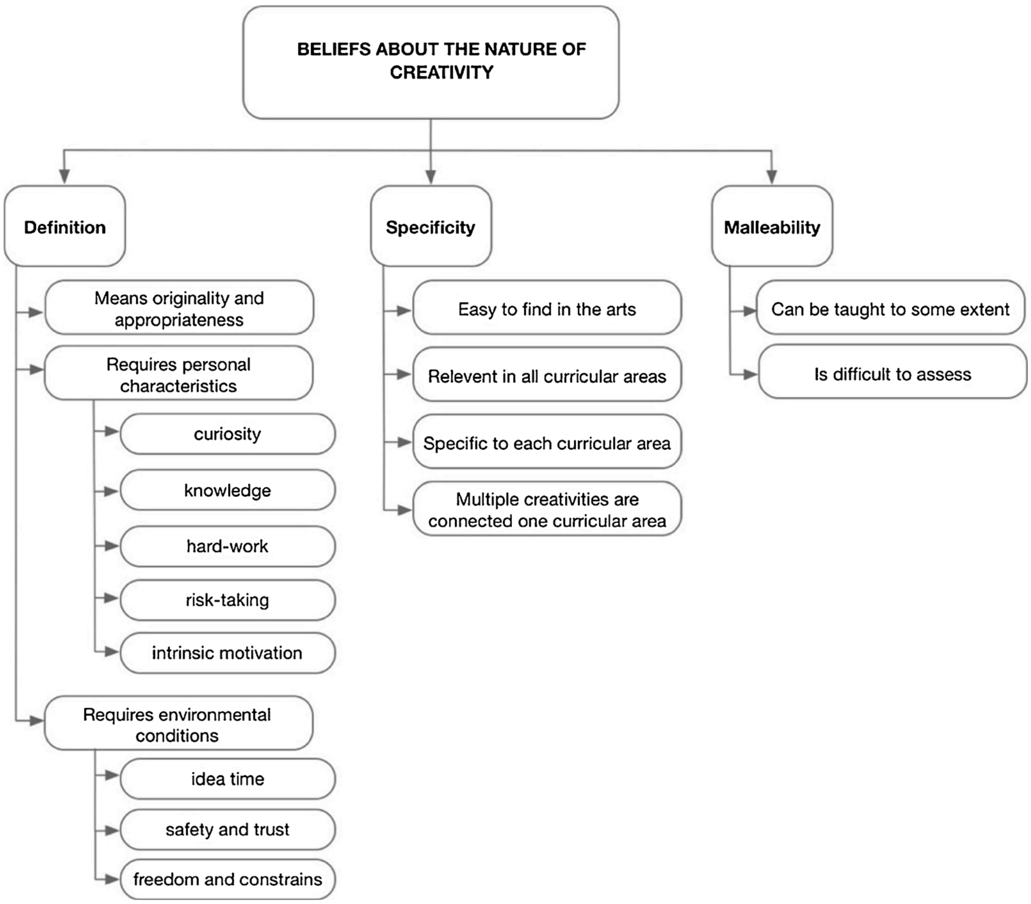

Fig. 1. Thematic Map Of Technology-Integration Expert Teachers' Epistemic Beliefs About Creativity.

expressed by Rose as follows: "I believe that each area has its own type of creativity". Moreover, all of them offered domain-specific conceptualizations. In visual and language arts, creativity was viewed as a form of artistic self-expression evident in creating or interpreting artistic products (Judith, Martha, Robert, Zoey); social studies teachers emphasised the problem-solving aspect of creativity (Boris, Elisabeth); EFL teachers viewed creativity as a way of original self-expression which was also appropriate to the situation, and dependent on one's language skills (Anita, Susan); mathematical creativity was connected to thinking in original and flexible ways to solve problems (Bill, Rose); science teachers also linked creativity with problem-solving and the scientific method of experimentation (Ada, Albert), as illustrated by Ada: "Experimenting is all about creativity".

Multiple creativities may manifest within one subject area. Six participants highlighted that creativity primary related to other subjects may also be nurtured in their classes (see Appendix C). For example, Ada, explained:

> A solution to a science problem may be creative […]. Creativity, then can be the design of an object, or model […]. Projects also have end-products, the creation of which require a form of creativity not connected strictly to the subject. For example, creating a movie, a poster, writing an article, is not a usual form of assessment in physics, and these tasks may require another form of creativity […].

4.1.3. *Malleability*

Two themes emerged in the area of malleability. Participants believed that creativity could, to a certain extent, be taught, and thought that it was difficult to assess.

Creativity can be nurtured in every student to a certain extent. All participants shared the belief that students' creativity can be increased. At the same time, some argued that development depends on students' inherent creative abilities, personal interests, and expectations (Anita, Boris, Martha, Susan), as explained by Susan:

> "I think that creativity can be fostered to a certain extent. If somebody is willing to or more prone to be creative, it can be fostered to greater extent, if not, then to a lesser one".

Creativity is difficult to assess. Six teachers believed that the assessment of creativity is problematic, citing various reasons for their view: the lack of appropriate measurement instruments (Judith), the dangers of providing inappropriate feedback that might discourage students' future creative efforts (Boris, Martha, Susan, Anita). One teacher (Bill) even considered assessment detrimental stating that "creativity cannot be assessed, because once we try that, we kill creativity". In contrast, six teachers (Ada, Albert, Robert, Rose, Elisabeth, Zoey) argued that creativity could and should be assessed, yet being vague about the specific strategies used.

4.2. *Teachers' pedagogical beliefs about fostering creativity with technology*

The analysis of interviews conducted with technology-integration expert teachers revealed six general themes with regard to their technology-supported creativity fostering pedagogical beliefs. These included valuing the use of technology to: (1) ignite students' creativity, (2) support students develop and explore ideas, (3) allow students create digital products, (4) scaffold students' creative thinking and production processes, (5) augment creative collaboration among students, and (6) facilitate the evaluation of creative student outcomes. Within these overarching themes, participants highlighted several subject-specific and -general uses of technology they believed could promote creativity within their own curricular areas. For a thematic map see Fig. 2. The complete coding analysis is provided in Appendix D.

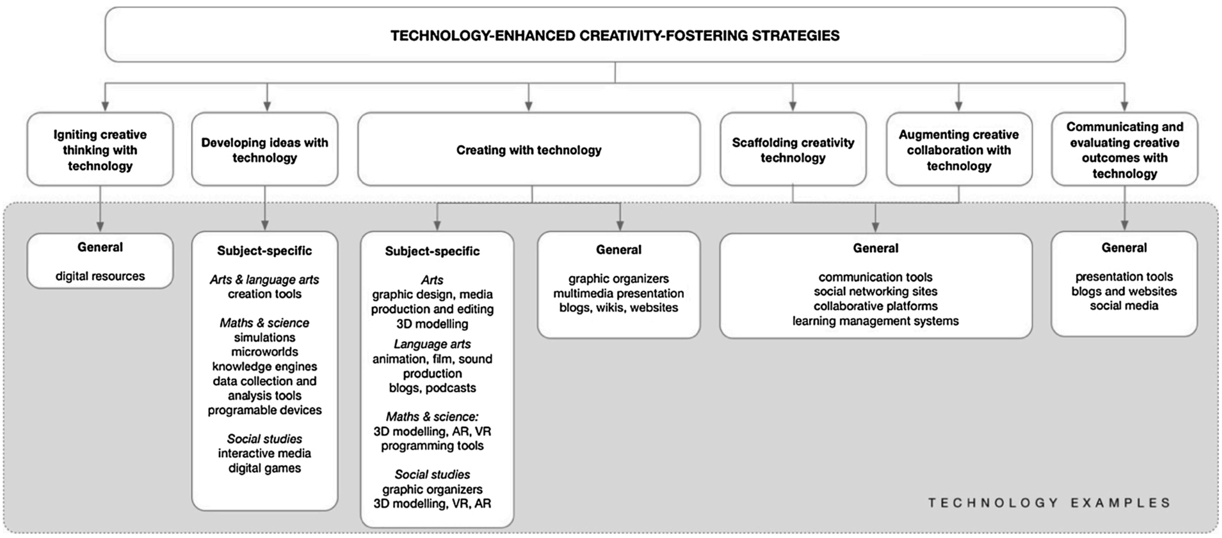

Fig. 2. Technology-integration expert teachers' pedagogical beliefs about nurturing creativity with technology.

4.2.1. Igniting students' creativity with technology: opportunities and challenges of subject-specific e-resources

Eight technology-integration expert teachers in the study explained how digital resources could be used in the classroom to spark students' interest and engage them in creative activities. Anita, for example, expressed the view that online images, audio, and video resources, as well as digital materials created by students themselves could provide valuable stimuli for creative language production in the EFL class:

> I don't want to say that anything [any resource] can be creative, and that it's all the same if I bring in some pictures from a magazine, or if kids take photos with their phones, because it isn't, because it's great that they themselves take the photos, which gives them a sense of ownership, that this is my photo, I chose it, freedom was involved.

In addition, online resources related to the subject content were reported to provide starting points for discussions about science phenomena (Ada, Albert), historical events (Boris, Elisabeth), or mathematical problems (Rose). Art teachers emphasised that artwork featured online could serve as a source of inspiration for students' own creative expression (Robert, Zoey). Two teachers (Zoey, Rose) noted, however, that the ease with which one could find information on the Internet made it tempting for students to copy rather than develop their own thoughts and ideas. For teachers examples in this category see Table 4. Table 4 also shows, that activities aimed at igniting students' creativity with technology were mainly associated with two instructional strategies: lecture and dialogues (whole class, group, dyad).

4.2.2. Supporting students' idea exploration and development with technology: subject-specific tools to foster subject-specific creative thinking

Eight teachers reported that they promoted students' creativity by designing and implementing technology-enabled activities that supported imaginative conjecture, exploration, and the representation of ideas offering several subject-specific examples. These involved the use of simulations, microworlds, and knowledge engines to allow students develop and test ideas during problem-solving in science and mathematics; the application of real data collection and analysis tools during student-led exploratory activities in science; utilizing content creation tools to try out ideas during fashioning activities in arts and language arts; and engaging students in creative thinking with subject-specific interactive media and digital games in social studies. For teachers' examples in this category see Table 5. Table 5 also shows that such activities were predominantly associated with inquiry-based learning, involving both independent and collaborative student work.

In the interviews, participants also highlighted several benefits of technology-based strategies in promoting students' idea development. For example, the two science teachers (Ada, Albert) argued that technology may allow students to explore specific phenomena, processes, or systems which would be difficult or impossible to explore without technology. Ada, for example, commented that:

> Then there are many simulations, which cannot substitute real-life experiments, because those are still better, but we cannot build a nuclear reactor in the classroom, or things connected to planets. I mean, when experiments are difficult to carry out in the classroom, it's great to use simulations in which one can manipulate variables. At the same time, this involves creativity, since it is up to the student which variables they choose to manipulate, and may discover variables that show an extraordinary phenomenon.

The benefits of digital authoring tools to support idea generation and verification were mentioned by language art and arts teachers (Martha, Zoey). In this regard, one art teacher explained:

Table 4
Teachers' examples of activities using e-resources viewed to ignite students' creative thinking across the curriculum.

Subject area	Activities using digital resources to engage students in creative thinking	Digital resources used
ART	Teacher presents digital art resources to inspire students creative expression. Students are asked to search for creative resources online as inspiration for artistic self-expression	online resources
EFL	Teacher selects and gives students humorous and puzzling digital images, sounds, videos as prompts for creative language production (oral or written).	online resources
	Student select and use digital images, sounds, videos as prompts for creative language production (oral or written).	teacher-created digital resources
	Student create puzzling and interesting images, sounds, videos to be used as prompts for creative language production (oral and written).	student-created digital resources
HUN	Teacher creates and uses digital quizzes with interesting questions to spark discussions.	teacher-created digital resources
MAT	Teacher creates and uses digital quizzes with interesting problems to spark discussions and prompt original and flexible ways of solving mathematical problems	teacher-created digital resources
	Teacher selects and shows videos about interesting mathematical problems as a starting point for classroom discussions.	online resources
SCI	Teacher selects and shows puzzling videos to students about scientific problems as a starting point for discussion.	online resources
	Students are presented with puzzling teacher-created photos and videos of phenomena before engaging in inquiry-based learning.	teacher-created digital resources
SOC	Teacher uses digital quizzes with puzzling questions on historical events as a starting point for discussions.	online resources
	Teacher shares interesting videos on historical events along with open-ended tasks.	teacher-created digital resources

Table 5
Teachers' examples of creative activities viewed to supported idea development and exploration across the curriculum.

Subject area	Activities supporting idea development and exploration with digital tools	Digital tools used
ART	Students use graphic design software to try out ideas while creating artistic products.	authoring tools
HUN	Students use collaborative word processing tools to edit and revise their work during creative writing activities (*Google Docs*).	authoring tools
MAT	Students use digital manipulative and visualization tools to develop ideas to solve mathematical problems (*GeoGebra*).	microworlds
	Students use knowledge engines to develop ideas to solve mathematical problems (*WolframAlpha*).	knowledge engines
SCI	Students take photos, record videos with mobile phones to develop understanding about phenomena during scientific inquiries and experiments.	data collection and analysis tools
	Students analyse images, videos, data with technology during scientific inquiries (*LabCamera*, *Excel*).	
	Students design data collection and collect data with mobile technology during scientific inquires.	
	Students use simulations to conduct experiments impossible or difficult to carry out in real-world settings (*Intellisense*, *Yenka*, *PhET*, *GeoGebra*).	simulations
	Students use programmable devices to test ideas during scientific inquiries (*micro:bit*, *Lego* robots).	programmable devices
	Students use knowledge engines to develop ideas while solving scientific problems (*WolframAlpha*).	knowledge engines
SOC	Students play commercial digital games to develop ideas related to historical events.	digital games
	Students use interactive resources to develop ideas related to historical events.	digital interactive resources

> When I was in college and wanted to try out colour variations, I was painting for days. Now it's one click. What I was doing manually for days, I can now do digitally in two minutes. There are much more possibilities to correct, change, revise, and this can help students a lot. (Zoey, Int. 2)

With respect to added value of technology for history, the two subject teachers (Boris, Elisabeth) noted that using commercial video games like *Assassins' Creed*, *Total War*, or *Civilization V* could promote students' subject knowledge and creative thinking in history, but considered their implementation complicated in school settings.

4.2.3. Allowing students to create with technology: expressing subject-specific and/or digital creativity

Eleven of the twelve participants highlighted the role of technology in giving students new opportunities to express their creativity by creating digital artefacts, which was the most widely cited category to promote creativity across the secondary curriculum (see Appendix D). The following Table 6 provides an on overview of digital creation activities reported by teachers. As Table 6 indicates, the instructional strategies used within this category involved predominantly project work and project-based learning, as well as practice-, problem- and design-based learning with students working in groups, or in some cases individually.

Table 6 shows that several digital production activities mentioned by teachers were aimed at building knowledge and argued to develop domain-specific creativity related to the primary focus of the curricular area (e.g. building 3D models in science, contributing to an online literary magazine in language arts, creating cultural podcasts for an international audience in EFL). Others, may allow students to express their understanding and learning while tapping in their creativity in the visual, written, and performance domains by producing digital media (e.g. students creating multimedia timelines about the history of science, or videos of solving mathematical problems).

4.2.4. Scaffolding students' creative processes with technology: towards blended creativity development

Ten teachers discussed how electronic environments and digital communication tools supported the facilitation and orchestration of student creativity in the classroom and beyond it (see Appendix D). The potential of technology to engage students in creative thinking beyond the classroom through sharing interesting resources along with open-ended tasks, and providing personalized feedback to ideas was highlighted by three teachers (Albert, Bill, Boris). Bill, for example, explained:

> I like Spiral [a one-to-one learning platform], because I can ask open-ended questions, and students can send in drawings, and I can give immediate feedback. […]. And then students describe their way of thinking, technology is very good for this.

Other teachers emphasised the support they provided for students during creative production activities in form of online mentoring, sharing resources, and facilitating communication and collaboration among them (Ada, Anita, Elisabeth, Judith, Robert, Rose, Susan, Zoey).

4.2.5. Augmenting creativity with technology: creative collaboration in electronic environments with peers

Seven teachers mentioned the role of technology in creative collaboration among students, which was predominantly valued in group projects and project-based learning (see Appendix D). Students were reported to have worked on shared documents, blogs, wikis, and webpages, which allowed them to create and refine products in groups both in and beyond the classroom. For example, Martha explained:

> It's great to work online, in let's say a shared *Google* document. You can take notes, edit, write, and the tool is capable of a lot of other things. […]. And it is creative because you have access to others' thought processes.

While technology may enable students to work in diversified groups with external collaborators, only one teacher in the study reported that her students sometimes participated in such activities, also adding that implementing such projects was too time-

Table 6
Teachers' examples of digital production activities associated with creativity-enhancement across the curriculum.

Subject area	Digital creation across the curriculum	Digital product
	Students take photos and manipulate images to demonstrate visual art skills while engaging in artistic self-expression.	Images
	Student create digital drawings to gain experience in the use of the tool while engaging in artistic self-expression	
ART	Students create digital infographics as products of self-guided inquiries in art history.	Graphic organizers
	Students create and edit films based on their own ideas using studied composition techniques.	Videos, animations
	Students create digital posters to advertise their own work.	Multimedia presentations
	Students design and print 3D objects to demonstrate knowledge of studied artistic and functional design principles.	Digital 3D modelling, holograms, AR/VR
	Students create and edit films role playing situations, dramatizing, or narrating stories using English.	Videos, animations
	Students create animations, narrate stories, or create subtitles in English (*PowToon*).	Multimedia presentations
	Students create multimedia presentations about a topic in English and present them to each other.	Games, quizzes
EFL	Students create digital language games and quizzes for peers (*Hot Potatoes*, *Kahoot*!, *Quizizz*).	
	Students write English language blogs to express opinions on topics.	Blogs, podcasts, webpages, wikis
	Students create English language podcasts about current issues for an international audience.	
	Students create digital cartoons to express their own interpretation of texts.	Images
	Students create and manipulate digital images to illustrate literary texts.	
	Students create memes to express own ideas and reactions to literary texts, or to express literary characters' ideas, feelings.	
	Students create imaginary radio interviews with literary characters.	Audio
	Students create films playing the role of literary characters or authors studied. Students create videos to express feelings, ideas about literary texts using moving images, photos created by them, or found online.	Videos, animations
	Students create short clips on exam topics using moving images, photos created by them, or found online.	
HUN	Students create digital multimedia books about a literary period or genre and share with each other.	Multimedia presentations
	Students create interactive multimedia posters or presentations about an author, a literary period, or a language topic (*Glogster*), and present them to each other.	
	Students create digital portfolios of creative writing products which they share with their teacher and peers.	
	Students share their creative writing pieces in student blogs.	Blogs, podcasts, webpages, wikis
	Students showcase their work on project webpage for larger audiences.	
	Students run an online literary magazine featuring their own poems, essays, book, film, and theatre reviews.	
	Students run and contribute to an online newspaper during media and communication project available for wider audiences.	
	Students create videos of mathematical problem-solving to demonstrate original and flexible thinking.	Videos, animations
MAT	Students create multimedia presentation to demonstrate understanding of mathematical concepts and show them to each other.	Multimedia presentation
	Students create multimedia timelines in history of science and speculate on future directions.	Graphic organizers
	Students create short clips of scientific experiments carried out by them. Students create documentaries on science phenomena using their own photos, moving images, or online resources.	Videos, animations
	Students create clips on final exam topics in science using moving images, photos created by them, or resources found online.	
	Students create interactive multimedia posters, presentations about scientific inquiries carried out by them (*Glogster*) and show these to each other.	
	Students create interactive posters to demonstrate inquiry-based learning featuring student created artefacts, procedures, and present these to each other (*Glogster*)	Multimedia presentations
SCI	Students create wikis about science topics for classroom use.	Blogs, podcasts, webpages, wikis
	Students create and run an online science magazine on a website during a project, and share it with wider audience.	
	Students feature their work and learning on the project website available for wider audiences.	
	Students design and print 3D models to solve science problems.	Digital 3D models, holograms, AR/VR
	Students create digital holograms to visualize scientific concepts.	
	Students create mobile applications related to science (*AppInventor*).	Programming
	Students create historical digital cartoons to illustrate historical problems.	Images
	Students create infographics about historic events and their consequences (*Piktochart*).	Graphic organizers
	Students create multimedia timelines of historical events featuring important dates, events, sources.	
	Students create digital flowcharts or mind maps to represent possible decisions of historical figures and possible consequences.	
SOC	Student create webpages featuring historical essays, games, and resources available for wider audiences.	Blogs, podcasts,webpages, wikis
	Students create *Facebook* pages for historical figures and post from their perspective.	
	Students create history quizzes and games for peers (*LearningApps, Kahoot*!).	Games, quizzes
	Students create mixed reality historical exhibition using VR/AR in the school.	Digital 3D modelling, holograms, AR/VR

consuming, and were therefore rare in her practice (Susan).

4.2.6. Evaluating creative outcomes with technology: looking for balance between relevance and safety

Nine teachers discussed explicitly how creative student products were presented, published, or communicated using technology, though the purpose, audience, and tools involved differed considerably (see Table 7).

Some teachers highlighted the role of technology in sharing creative outcomes with peers, or presenting them in the classroom to showcase and celebrate creative achievements, which were argued to lead to higher quality products (Anita, Zoey, Judith). Student-created products were also made available for wider audiences on project websites (Elisabeth, Judith, Martha, Zoey, Judith).

Technology was also connected to more advanced forms of authentic creativity assessment. Creating specifically for peers (e.g. quizzes, games, or learning materials) was suggested to give more relevance to student work, which in turn was viewed to lead to more thoughtful products (Elisabeth, Judith, Susan). Examples of creating for and sharing creative outcomes with audiences outside the classroom using technology included: publishing an English language podcasts on current Hungarian issues (Anita), sharing student art on social media sites (Robert), entering literary competitions with videos and digital art, or running an online school magazine (Judith).

However, one teacher (Anita) noted that asking students to share or publish their work electronically should always be treated with caution "I might be overcautious, but I am very careful about who shares what even if we are in a closed group", since some students may not be ready to take the risk of presenting their work and potentially facing criticism.

4.3. Technology-integration expert teachers' enacted beliefs of nurturing creativity with technology

While interview data exposed teachers' beliefs about creativity and its nurture, classroom observation, and document analysis provided insights on how technology-integration expert teachers enacted these beliefs. Overviews of the observed classes and documents analysed are provided in Appendices A and B.

4.3.1. Teachers' epistemic beliefs about creativity and their technology-enhanced creativity fostering practice

The analysis of classroom observation (O) and document analysis (D) showed that teachers' practices were in general alignment with several beliefs – both those research-aligned and those contrasting – they expressed in the interviews, while considerable incongruence was found in the area of definition (viz. environmental conditions) and malleability (viz. assessment) as shown in Table 8.

4.3.1.1. Definition: No originality bias, creativity cultivated along with knowledge, but variations in creativity environment. Teachers cultivated creativity along with subject-specific knowledge. In all the observed lessons, students were required to use or build content knowledge and skills during technology-supported creativity-fostering activities, while the appropriateness of student ideas and outcomes were often discussed.

In terms of the environmental conditions, there was incongruence between teachers' espoused beliefs and technology-based creativity-fostering practice across several cases. While 11 teachers in the study argued that idea time is necessary for creativity (see Appendix C), time for students to develop ideas, work at their own pace, and use time flexibly was limited in four of the observed lessons (Bill, O; Boris, O; Robert, O; Rose, O; Zoey, O). Freedom and choice was also mentioned as important characteristics of the creative environment by nine teachers, yet four of them (Bill, O; Robert, O; Rose, O; Zoey, O) implemented more teacher-centered approaches (see Appendix A).

In turn, the analysis of documents indicated that several participants who applied teacher-centered approaches in the observed lesson offered students time to develop ideas as well as freedom and choice in technology-based creativity-fostering activities during project- and inquiry-based learning, outside the normal curricular time frames (Boris, D1; Elisabeth, D1; Rose, D2; O; Zoey, D1, D2).

4.3.1.2. Specificity: No evident arts bias, subject-specific and cross-curricular creativity-fostering aims. The analysis of observations and documents revealed no arts bias in teachers' classroom practices, in line with their expressed beliefs. In addition, findings highlighted general alignment between subject-specific conceptions of creativity and technology-enhanced creativity-fostering instructional aims in all cases.

Teachers expressed the view that creativity from different domains could be promoted in their classes. This was observable in their practice, too (Elisabeth, O; Rose, O). Creating infographics on the French Revolution in Elisabeth's social studies class, for example, offered students opportunity to express creativity in the visual media domain while intended to promote knowledge building in history. The documentation of several projects showed that students often needed to tap into their verbal, written, visual, and performance creativity – gained in classes of art and language art – when communicating learning and the results of their inquires through

Table 7
The purposes, audiences, and tools involved in communicate and evaluating student outcomes identified in Study 2.

Audience	Purpose	Digital tools used
peers, wider audience teachers, peers specific audience	to showcase creativity to get teacher and peer feedback to get real world feedback	presentation tools, collaborative platforms, LMSs, Web 2.0 tools, social media

Table 8
Teachers' epistemic beliefs about creativity and their technology-based creativity-fostering practice.

Participants		Relationship between creativity beliefs and practice by data sources					
Subj. code	*Participant*	*Definition*		*Specificity*		*Malleability*	
		Obs.	*Doc.*	*Obs.*	*Doc.*	*Obs.*	*Doc*
EFL	Anita	+	+	+	+	+*	+*
	Susan	+	+	+	+	+*	ne
SOC	Boris	≈	+	+	+	+*	+*
	Elisabeth	≈	+	+	+	≈	≈
HUN	Judith	+	+	+	+	+*	+*
	Martha	+	+	+	+	+*	+*
MAT	Bill	≈	+	+	+	+*	ne
	Rose	≈	+	+	+	≈	≈
SCI	Ada	+	+	+	+	≈	+
	Albert	ne	+	ne	+	ne	≈
ART	Robert	≈	+	+	+	≈	ne
	Zoey	≈	+	+	+	≈	≈

Note: + /congruence between creativity beliefs and practice, ≈ partial congruence between creativity beliefs and practice; */beliefs incongruent with creativity research (assessment), ne/no evidence identifiable in the data.

media technology (Ada, D1, D2; Albert, D1; Boris, D1; Judith, D1; Rose, D1).

4.3.1.3. Malleability: democratic creativity-fostering instruction, but limited evaluation and assessment practices.. The analysis of practice reflected teachers' view that creativity can be nurtured in all students, since they implemented creativity-fostering activities with every student in the lessons observed, while documents also referenced the participation of regular student groups.

Observation and document analysis confirmed that the assessment of creativity was problematic for most teachers. In some classes, student products were shared with the teacher and peers to showcase creativity (Elisabeth, O), and/or evaluated for quality and accuracy (Anita, O; Susan, O). Nevertheless, creativity was not discussed or evaluated per se in any observed class. Project documents contained various assessment forms, such as product rubrics, peer evaluation (Albert, D1 Boris, D1; Judith, D1; Rose, D1; Zoey, D1), yet the evaluation of creativity was only referenced in one document (Ada, D1.): Ada included creativity into the product evaluation rubric of the online science magazine articles her students were asked to create in a project.

4.3.2. Teachers' pedagogical beliefs about fostering creativity with technology and their practice

4.3.2.1. Alignment between teachers' pedagogical beliefs about fostering creativity with technology and their practice. The analysis of classroom observations and pedagogical documents revealed the same themes with regard to technology-enhanced approaches across the secondary curriculum identified in the interviews. Table 9 provides an overview of the themes across the three data sources.

Igniting creativity with technology emerged from observation data as the most widely applied technology-enhanced instructional approach implemented in seven lessons (Anita, O; Bill, O; Boris, O; Robert, O; Martha, O., Rose, O; Zoey, O), and being the only method in three lessons (Boris, O; Robert, O; Rose, O). For example, the two art teachers showed humorous and thought-provoking artwork to their students to provide them with inspiration for subsequent artistic production tasks (Robert, O.; Zoey, O). Bill (O) and Boris (O) created quizzes in history and mathematics with the puzzling questions and used them as starting points for whole class discussions. In Anita's EFL class students took photos in the school building to be used as prompts for their subsequent creative language production (Anita, O). Igniting creativity with technology as a theme also appeared in the documents analysed (Ada, D1, D2; Judith, D1, D2; Rose, D1). For example, Rose (D1) showed puzzling videos to encourage students' engagement in brainstorming and problem-solving related to environmental issues in an interdisciplinary project, while Judith (D1) asked students to watch a fake documentary before embarking on a week-long project on fake news in language arts.

Developing and exploring ideas with technology were observed in four lessons (Ada, O; Bill, O; Elisabeth, O; Judith, O; Zoey, O). During inquiry-based learning about motion in physics, Ada's students used a variety of technology, such as programmable devices (*micro:bit*, *Lego robots*), data collection and analysis tools (*mobile phones, LabCamera*) to develop solutions, test ideas, and build models. Bill's

Table 9
An overview of technology-enhanced creative activities across data sources.

Themes	Number of participants		
	Interviews	*Observations*	*Documents*
Igniting creativity with technology	8	7	3
Developing and exploring ideas with technology	8	5	4
Creating with technology	11	4	8
Scaffolding creative processes with technology	10	3	6
Augmenting creative collaboration with technology	8	3	5
Evaluating creative outcomes with technology	9	4	3

Table 10
The CFP of teachers' technology-based creativity-fostering practice.

Participants	Subj. code	Classroom observations							Documents
		SCALE (range 0–3)				*Technology-based creativity fostering approach*	*Level of technology integration in the creativity-fostering approach*	*CFP Obs.*	*CFP Doc.*
		Physical environment	Learning climate	Learner engagement	Total				
Ada	SCI	3.00	3.00	3.00	3.00	DEIT CT CT SCT ACT	Transformation Transformation Amplification Amplification Amplification	High	High
Martha	HUN	1.75	3.00	3.00	2.62	ICT CT	Amplification Transformation	High	High
Anita	EFL	1.50	3.00	2.83	2.46	ICT ECT	Transformation Amplification	High	High
Susan	EFL	1.25	2.33	3.00	2.31	CT ECT	Amplification Transformation	High	NE
Elisabeth	SOC	3.00	1.33	2.33	2.31	ECT DEIT CT SCT ACT	Replacement Amplification Amplification Amplification Amplification	Medium	High
Judith	HUN	1.00	2.67	2.00	1.85	DEIT CT ACT SCT ECT	Amplification Amplification Replacement Amplification Amplification	Medium	High
Zoey	ART	1.25	1.67	1.83	1.62	ICT DEIT	Amplification Amplification	Medium	High
Bill	MAT	.50	1.67	1.83	1.38	ICT DEIT	Replacement Transformation	Modest	NE
Rose	MAT	.75	2.00	1.50	1.38	ICT	Amplification	Modest	High
Robert	ART	.50	.67	1.17	1.08	ICT	Amplification	Modest	NE
Boris	SOC	.75	.67	1.00	.85	ICT	Replacement	Modest	High
		M *SD*	*M* *SD*	*M* *SD*	*M* *SD*				
Sample		*1.39* *.89*	*2.00* *.88*	*2.14* *.75*	*1.87* *.72*				

Note. ICT - Igniting creativity with technology, DEIT- Developing and exploring ideas with technology, CT - Creating with technology, SCT - Scaffolding creative processes with technology, ACT - Augmenting creative collaboration with technology, ECT - Evaluating creative outcomes with technology.

students were prompted to use the microworld *GeoGebra,* and the knowledge engine *WolframAlpha* to develop, explore, and test their ideas while solving mathematical problems. Judith's students revised and refined their ideas while writing collaboratively the synopsis of a modern day drama reinterpretation in *Google Docs*, and also used online resources as input when needed to further expand their thinking. In Zoey's arts class students searched the Internet for artwork to develop ideas for their Mona Lisa reinventions. Document analysis revealed using similar technology-based approaches to promote idea development and exploration in projects, project- and inquiry-based learning (Ada, D1, D2; Albert, D1; Rose, D1; Judith, D1, D2).

While the most widely cited technology-enhanced creativity-fostering approach during the interviews was *creating with technology*, there were only four teachers who implemented such activities in the classes observed (Ada, O; Judith, O; Martha, O; Elisabeth, O). In four others, students were asked to create digital artefacts as homework (Susan, O; Rose, O; Zoey, O; Robert, O). In the lessons observed, Ada's students, for example, created multimedia journals for their experiments, Judith's class wrote screenplays collaboratively in *Google Docs*, Martha's students created poetry videos, while early finishers in Elisabeth's class worked on their history webpage project. The instances exemplified both domain-specific creative production (Judith, Martha) as well as expressing creativity through digital media to demonstrate understanding and learning (Ada, Elisabeth). Project documentation also contained references to several digital student products, such as: memes, posters, ebooks, quizzes, videos, blogs and websites in literary, language, and media projects (Martha, D1; Judith, D1); mobile phone applications, 3D models, holograms in science projects (Ada, D1, D2; Albert, D1); timelines, mindmaps, and websites with articles on historical problems in social science (Boris, D1; Elisabeth, D1); and 3D models and prints in arts (Zoey, D1, D2). The analysed documents also referenced multimedia presentations created by students to showcase their learning (Ada, D1; Albert, D1; Boris, D1; Rose, D1).

Scaffolding creativity with technology emerged in three observed lessons (Ada, O; Elizabeth, O; Judith, O). Teachers shared open-ended tasks along with digital resources for students to access during inquiries, monitored groups during creative production, and provided online guidance. Findings of the document analysis highlighted that teachers used technology to scaffold students' creative production during project-work and project-based learning (Ada D1, D2; Albert D1; Boris, D1; Judith, D1, D2; Martha D1).

Augmenting creativity with technology was observed in three classes (Ada, O; Elisabeth, O; Judith, O). Ada's students used *OneNote* to collaborate in groups and co-create digital diaries of experiments during inquiry-based learning, Judith's students worked collaboratively in groups on a creative writing task in *Google Docs*, while Elizabeth's students co-created webpages. Collaborating with technology during creative activities was also a recurring theme identified in the documents. Students were referenced to use collaborative platforms which supported their creative production (e.g. electronic communication, files sharing, collaborative documents) and allowed them to co-create digital products (e.g. blog, webpage, wiki) (Ada, D1, D2; Judith, D1, D2; Martha, D1). Yet, no evidence for electronic collaboration with individuals other than peers and teachers was observed in any of the lessons or found in any of the documents.

Evaluating creative outcomes with technology emerged in five observed lessons (Anita, O; Elisabeth, O; Susan, O; Judith, O). Anita's students, for example, shared their voice presentations with peers and the teacher, and received individual feedback on the quality and content of their products in the EFL class observed. Students' in Susan's EFL class played and critiqued each other's *Kahoot!* quizzes. Elisabeth's students presented their history infographics and received feedback on accuracy and design from teacher and peers, while Judith's students provided feedback on each other's drama scripts in *Google Docs*. Creativity as criterion for feedback or assessment, nevertheless, was not discussed in any of the observed classes. Documents also revealed that students' creative outcomes were often communicated using technology. Several student-created artefacts were featured on public websites (Elisabeth, D1; Judith, D2; Martha, D1, Zoey, D2). Project descriptions also referenced multimedia presentations which students could showcase their learning, and possibly their creativity (Ada, D1, D2; Albert, D1; Boris, D1; Judith, D1; Rose, D1). Nevertheless, students' creative development was rarely monitored, and creative outcomes were rarely assessed for creativity during projects (with the exception of Ada, D1).

4.3.2.2. Variations in the creativity-fostering potential of teachers' technology-based practices. Finding alignment among participant teachers' technology-enhanced creativity-fostering beliefs and practices does not mean that all teachers' practices were similar in terms of their creativity-fostering potential (CFP). Table 10 below summarises related results including: the support for creativity in the learning environment in the observed classes determined by SCALE (Richardson & Mishra, 2018), the technology-based creativity-fostering strategies used, the level of technology integration based on Hughes et al. (2006), as well as the overall CFP of the observed lessons, and that of the teaching instruction illustrated by the documents.

Teachers' practices in the observed lessons differed substantially with respect to the support for creativity they provided in the learning environment determined through SCALE ($M = 1.87$; $SD = .72$). Variations were also identified within the subdimensions (Physical environment, $M = 1.39$, $SD = .89$; Learning Climate, $M = 2.00$, $SD = .88$; Learner engagement, $M = 2.14$, $SD = .75$). Expert teachers worked with students in very different physical environments, some with very limited resources and flexibility (Bill, O.; Robert, O.; Rose; Boris, O), while establishing a learning climate for creativity and engaging students in creativity-fostering tasks seemed especially problematic with large classes and limited curricular time frames (Boris, O.; Robert, O; Zoey, O). It is important to note, nevertheless, that two teachers' practices were more modest, despite small class-size and more curricular time (Bill, Rose).

Table 10 also indicates that the level of technology integration to promote creativity in the observed lesson varied considerably among participants based on RAT (Hughes et al., 2006).

We identified four instances of *replacement,* when technology was used to substitute but in no way to change creativity-relevant instructional methods, student learning process, or curricular goals. Interesting problems were projected to students followed by discussions and questioning in two cases (Bill, Boris), which could have been shared with students without using technology, too. In Judith's class small student groups were asked to work collaboratively in *Google Docs* on a creative writing task, yet they collaborated in person at one computer, rather than accessing the same shared document individually. Finally, in Elisabeth's class students' infographics were projected and discussed as in frontal manner. Thus, technology did not improve or change the way feedback was provided to students' work or the audience.

We identified 18 instances of *amplification* when technology was used to extend creativity-fostering practices increasing their efficiency or productivity without changing their nature. Teachers enriched the curriculum by selecting and presenting interesting digital images to engage students in subsequent creative thinking activities (Rose, Boris), or by allowing students themselves to search the Internet for resources to develop ideas for creative production (Judith, Zoey). Authoring tools allowed students to try out their ideas (Judith), and create more complex multimedia products (e.g. multimedia journals of experiments, websites, quizzes) (Ada, Elisabeth, Susan). Collaborative tools extended ways students could work together on creative tasks in the classroom (Ada, Elisabeth, Judith), LMSs made the scaffolding creative production and monitoring of student work easier (Ada, Elisabeth, Judith), while LMSs, sharing, and annotation tools allowed personalized and timely feedback to student ideas or products (Anita, Judith).

Finally, we found only five instances in which technology *transformed* creativity-fostering instruction by creating entirely new teaching and learning processes, or new curricular goals in teachers' observed classes. Examples included students' taking personally relevant photos to be used as prompts for subsequent creative thinking activities in the EFL class (Anita); students using microworld and knowledge engine in maths (Bill) as well as programmable devices, and various data collection and analysis tools in science (Ada) to develop, explore, and test ideas during self-directed inquiries. Students created personally meaningful poetry videos in language arts (Martha), and staged a quiz show using *Kahoot!* in an EFL review lesson for authentic assessment (Susan). Transformation, as the highest level of technology integration, was not identified in the area of scaffolding and collaboration. Collaboration among students and scaffolding creative processes by teachers did not go beyond the classroom in the observed lesson, while collaborations did not involve external parties.

Comparing classroom observation data with document analysis suggested that most teachers whose practices was more limited in the observed lessons (Boris, Elisabeth, Judith, Rose, Zoey) were also able to implement more advanced technology-based creativity-fostering instruction outside the regular curricular frames (i.e. during project weeks). See Table 10 and Appendix B.

5. Discussion

5.1. Teachers' epistemic beliefs about creativity

Our first research question concerned technology-integration expert secondary school teachers' pedagogical beliefs about the nature of creativity, since these may enable or limit their technology-enhanced creativity-fostering views and practices (Andiliou & Murphy, 2010; Skiba et al., 2017). Our study found overall alignment between participants' beliefs about creativity and scientific theories in the area definition and specificity, but limiting views with regards to assessment.

5.1.1. Enabling beliefs: research aligned views about definition, specificity and distribution

In line with the literature teachers in this study acknowledged both originality and appropriateness as joint requirements for creativity, appeared to be aware of several important creative-person characteristics (curiosity, knowledge, hard work, risk-taking, intrinsic motivation, and imagination) as well as environmental conditions (idea time, safety and trust, balance between freedom and constraints) necessary for creativity. Though many teachers expressed the view that creativity is easier to find in the arts, they cultivated domain-specific conceptions of creativity, and were able to establish a clear relationship between creativity and their own curricular area. Also, participants generally believed that creativity can be fostered in every student across the secondary curriculum. These findings are in contrast with previous research which highlighted limited views and several misconceptions (i.e. originality and arts bias) about creativity among educators, also suggesting that such beliefs may be detrimental for students' creative growth (Andiliou & Murphy, 2010; Bereczki & Kárpáti, 2018; Mullet et al., 2016). At the same time, our research brings further evidence to the smaller body of knowledge on highly accomplished teachers, which associates advanced pedagogical practices with research grounded beliefs about creativity (e.g. Henriksen & Mishra, 2015; Merriman, 2015; Scott, 2015).

5.1.2. 5.1.2Limiting belief: conflicted views about assessment

Assessment has increasingly been recognized as a key issue of creativity education (Vincent-Lancrin et al., 2019). Teachers in this study expressed different views regarding the assessment of creativity, which was seen problematic by many participants due to lack of appropriate measures, to perceived threats proposed by inappropriate measurement, or because teachers believed that the concept could not be measured. Thus, while measures of creativity have been used in research for decades (Kaufman, Plucker, & Baer, 2008) and assessments for classroom exist (Skiba et al., 2017; Vincent-Lancrin et al., 2019), these still need to be scaled and further developed to fit classroom use. The finding that even highly accomplished teachers need support in this area establishes *creativity assessment as critical point of teacher professional development*, be it within or beyond the context of technology-supported creativity enhancement.

5.2. Teachers' technology-based creativity enhancement views

Our second research question asked about teachers' technology-based creativity fostering views. Data analysis revealed six general technology-based approaches deemed relevant by expert teachers in promoting creativity with technology across the curriculum, as well as several subject-specific and general technology-based instructional strategies.

5.2.1. Overarching technology-based creativity-fostering approaches, subject-specific and general strategies

Expert teachers in this study valued six overarching technology-enhanced creativity-fostering approaches across the curriculum: *(1) igniting students' creativity; (2) supporting idea development; (3) creating digital products; (4) scaffolding students' creative processes; (5) augmenting creative collaboration among students; and (6) facilitating the evaluation of creative student outcomes*. Within these general approaches, teachers also identified several both subject-specific and general strategies to promote creativity with technology (See Fig. 2).

The main approaches of promoting creativity with technology emerging from expert teachers' views and experiences are overall convergent with existing theoretical models (Glăveanu et al., 2019; Loveless, 2003, 2007), which also highlight the distinctive role of technology in idea production and verification, creation, the management of creative processes, creative collaboration, and the evaluation of creative outcomes. Yet, the approaches identified here, being grounded in teachers' actuals views and practices, together might provide a framework better aligned with the realities of the classroom.

In addition, one element that was not explicitly addressed in the scientific models is the role of technology *to support creative intent* (i.e. igniting students' creativity). Activities exemplifying this theme were aimed at motivating students to engage in consecutive creative thinking and production activities. Educators generally believe that technology has a distinct role in supporting student motivation and engagement (Ertmer et al., 2015; Tondeur et al., 2017), while our findings indicate that they also seem to hold this view in relation to creativity as suggested by a few previous studies (Adams, 2013; Alsahou, 2015). The practical relevance of supporting creative intent with technology, thus highlights a need of its inclusion in pedagogical frameworks of promoting creativity with technology.

While several technology-based creativity-enhancement strategies were valued in different areas of the curriculum, others were highly subject-specific. In particular, technology-based approaches that support idea development and exploration as well as domain-specific creative production differed substantially, reflecting that creativity in different domains also involves specialized skills, and strategies (Amabile, 1996; Baer & Kaufman, 2005), while their support requires specialized technology tools. At the same time, the general approaches identified suggest that certain technology-based creativity-approaches have relevance across the whole curriculum.

5.2.2. Digital production: subject-specific and/or digital creativity?

Within the category of creating with technology, the most widely-cited approach to fostering creativity with technology by participants, we identified *both distinct subject-specific and more general strategies*. Many activities reported by teachers asked students to create digital products expressing their domain-specific creativity (e.g. graphic design and 3D software in arts; programming and 3D modelling in science; creative self-expression through media production in language arts). Others were supposed to encourage students to demonstrate their learning and understanding of curricular content through tapping into their creativity in written, visual, or performance domains by producing digital media (e.g. multimedia presentations, wikis, websites, games, quizzes).

Creativity researchers argue that creating purposeful outcomes across the curriculum represents a viable strategy for nurturing creativity (Craft, 2005; Cropley, 2011; Renzulli, 2017), pointing out at the same time that product bias – i.e. the view that creativity requires the production of tangible outcomes – could also act as a barrier to creativity-enhancement (Andiliou & Murphy, 2010; Beghetto, 2010). Teachers in this study show to some extent *a digital product bias.* However, given the versatility of digital creation opportunities offered by technology and the emphasis on teaching digital competence in education (European Commission, 2018), this focus may be appropriate in the classroom. *Yet, without specifying what kind of creativity is required from students in these contexts and without scaffolding subject-specific and/or cross-domain creative processes, such activities, - though they might be beneficial for learning, - do not optimally promote students' creative growth.*

5.3. Teachers' enacted beliefs of nurturing creativity with technology

The third research question concerned the enactment of technology-integration expert secondary school teachers' beliefs about creativity and its nurture through digital tools. Similarly to other studies investigating the relationship between beliefs and practice related to creativity (Bereczki & Kárpáti, 2018) and other areas (Fives & Buehl, 2012), we found both congruences and incongruences. In addition, there was considerable variance among teachers with respect to the creativity-fostering potential of their practice both across and within the cases. While several studies found that teachers cannot or do not enact their creativity-fostering pedagogical beliefs (e.g. Konstantinidou & Zisi, 2017; Schachter, Thum, & Zifkin, 2006), our study offers a more nuanced picture, with several teachers being able to implement high quality practice in alignment with their beliefs. Here we highlight those findings that could provide future entry points for the improvement of technology-based creativity instruction in schools.

5.3.1. Limited creativity assessment practices

Teachers' epistemic beliefs about creativity identified in the interviews were generally reflected in their technology-based practices. Observation and document analysis highlighted that, in line with scientific theories, teachers cultivated creativity in conjunction with academic learning, technology-based creativity-fostering instruction was embedded in the context of or specific to the subject they taught, and targeted all students, not just a select few. At the same time, the investigation of practice confirmed that the evaluation and assessment of creativity is a problematic aspect of instruction, since students' creative capacities or the creativity of student outcomes were rarely discussed or assessed per se (with the expiation Ada's case). *Insecurities about how to assess creativity may thus represent a considerable internal barrier even for expert teachers, and thus requires special attention in teacher education and professional development.*

5.3.2. Challenges of implementing technology-enhanced creativity-fostering instruction in regular classes

Teachers' views about the role of technology in fostering creativity were also evident in their instruction, as they implemented all six technology-enhanced creativity fostering approaches identified in the interviews. Allowing students to create with technology, engaging them in technology-based inquires and collaboration were implemented by few teachers in the observed lesson (Ada, Martha, Susan, Judith). Documents and interviews, on the other hand, showed a preponderance of such activities, suggesting that more time-consuming technology-based creativity-fostering strategies might not be realized within regular classes.

Similarly, though most teachers were aware of the key characteristics of creativity-conducive environments, the support for creativity in the observed lessons measured by SCALE (Richardson & Mishra, 2018) differed considerably ($M = 1.87$; $SD = .72$), with five participants having difficulties in this area (Bill, Boris, Robert, Rose, Zoey). Yet, three of them (Boris, Rose, Zoey) were able to provide students with more freedom, choice, and self-directed active learning opportunities outside the regular curricular timeframes (i.e. during project weeks). This suggests that both internal (e.g. limited creativity-fostering pedagogical knowledge) and external barriers (e.g. inappropriate physical environment, limited time) may hinder teachers technology-based creativity-fostering instruction, and *that even highly accomplished teachers need help to address the limitations of their school environments.*

5.3.3. A need for shift towards transformative uses of technology to promote creativity

In this study, participants' technology-based creativity-fostering strategies were evaluated using the RAT framework adapted from Hughes et al. (2006). Our results show that replacement, the most modest level of technology integration, occurred only in few instances, while most teachers used digital tools to amplify creativity-relevant teaching and learning in their classes. Yet, four managed to implement transformative practices with high potential, and illustrated that technology can be a powerful tool to support students' creativity-relevant motivation and engagement, idea development and exploration, creation, as well as to promote authentic assessment practices. The full potential of technology to scaffold creative processes and augment creative collaboration, though valued by several teachers in this study, were not demonstrated. *The adapted RAT model, then, could serve as a useful tool to support the improvement of educators' pedagogical technological content knowledge (TPACK,* Mishra & Koehler, 2006*) about fostering creativity, an area even technology-integration expert teachers need assistance with.*

5.4. Gaps between practice and research in the area of technology-enhanced creativity

One of the main goals of this study was to provide research with themes grounded in the realities of classroom. Teachers in this study valued and implemented several technology-based creativity-fostering approaches in line with previous research findings. At the same time, certain strategies and approaches were less emphasized in existing research.

Several studies suggest that the electronic scaffolding of creative thinking and problem-solving, (Chang, 2013; Kao et al., 2017; Kuo et al., 2014), creative collaboration in electronic environments (Chen & Chiu, 2016; Usher & Barak, 2019), creative production, more specifically the instructional use of special design (*3D-Cad*) (Chang, 2014; Chang et al., 2019) and arts (*ePainting*) (Ho et al., 2017) software might be effective for promoting students' domain-specific creativity. These approaches were also valued and applied to a certain extent by teachers in this study. Technology-based problem-solving interventions (Chang, 2013; Kao et al., 2017; Kuo et al., 2014) also show similarity with the inquiry- and the design-based instruction described by the science teachers in this study. Yet, our participants' implementations seemed more prosodic, while long-term holistic creativity-fostering approaches were absent from practice.

The intervention literature reviewed, on the other hand, provided limited evidence on the effectiveness of creativity-focused implementation and conditions of several subject-specific and -general approaches deemed valuable by participants for: idea development (e.g. the use of microworlds, knowledge engines, simulations data collection and analysis tool, programmable devices in STEM), creation in different digital media genres (e.g. blogs, wikis, podcasts, videos, animations, multimedia etc.), and the application of serious and commercial videogames in secondary school subjects. Also, it is important to note, that while participants used commercially available applications, most previous studies reviewed involved newly developed tools, environments, and materials, and only few focused *on readily available resources*, that can be easily implemented by teachers. This study points to several such opportunities.

6. Limitations

First, limitations include those commonly associated with case studies, namely that findings are not appropriate for generalization. Instead of generalizability, this study supports transferability. By providing a detailed description of the participating technology-integration expert teachers' beliefs and experiences as well as their contexts, others can evaluate the extent to which the conclusions drawn are transferable to other situations, times, and settings. Second, given that teachers in this study were selected on the basis of their expertise in technology integration, implications may only apply to similar teacher groups. Nevertheless, an expert sample was specifically chosen due to their role in informing practice and research about technology-enhanced creativity-fostering activities valuable for the classroom. In addition, participants taught in secondary schools, which may also limit the range of implications. Subsequent research would, therefore, benefit from involving more traditional classroom teachers, and from lower education levels to extend the findings of this case study. Third, to investigate teachers' beliefs and their enactment, data were collected through interviews, classroom observations, and document analysis. Nevertheless, due to limited funds, time, and participant access, only one site visit to each teacher was undertaken, which may not allow for an accurate portrayal of teachers' beliefs in action. Future studies may include longitudinal investigations to better document teachers' beliefs and experiences. Finally, data for the present study were drawn from teachers' self-reports and observation of practice. Future research could incorporate students' perspectives too, to provide a more in-depth description of the phenomena presented in this paper.

7. Conclusions and implications

This study explored educational technology-integration expert teachers' beliefs about and experiences with nurturing creativity with technology to identify themes and research questions grounded in the realities of the classroom, as well as to support policy, teacher education, and practice in the area of technology-enhanced creativity education. Our study provided evidence that technology-enhanced expert teachers' epistemic beliefs about creativity influence their technology-based creativity fostering practices, and established creativity assessment as a critical area of teacher development. The study also offered a classroom grounded framework for evaluating and guiding the integration of technology into creativity-fostering instruction aligned with teachers actual experiences, and relevant across the secondary school curriculum. The framework also includes a new approach with important educational relevance: supporting creative intent with technology. From the investigation of the enactment of teachers' beliefs it can be concluded that even expert teachers need support with implementing creativity assessment and technology-based creativity-fostering practices in regular curricular timeframes, as well as with accomplishing higher levels of technology integration. Finally, the study highlighted several subject-specific and general strategies valued and implemented by teachers, providing pointers for future research on the effectiveness of technology-based creativity enhancement with practical relevance.

7.1. Implications for policy, teacher education, and practice

The study has several implications that could further the promotion of creativity through technology in any country where creativity enhancement and digital literacy are important teaching and learning objectives:

- Our study found that teachers' creativity beliefs impact their technology-based creativity-fostering practices. Therefore, beyond establishing creativity as a learning outcome, policy documents should include domain-specific conceptualizations highlighting both subject-specific and cross-curricular implications, and explain the related roles of technology. This might help teachers develop research aligned views about creativity, as well as differentiate between promoting subject-specific creativity and creativity linked to digital communication and learning, and increase the effectiveness of both approaches.
- Professional development should discuss the definition as well as the domain-specific and -general aspects of creativity, and demonstrate successful assessment practices. Our study revealed that the assessment of creativity is a key area which should be specifically targeted in professional development, be it with technology or without.
- Education technology courses should explicitly focus on the pedagogical use of both subject-specific and -general technology approaches to promote creativity and demonstrate best practices of transformative technology uses to promote creativity.
- Professional development should also prepare educators to address the challenges of promoting creativity in unfavorable school environments.

7.2. Implications for future research

Being of an exploratory nature, our study raises a number of opportunities for future research at the intersections of creativity, technology, learning with relevance for classroom practice:

- Future studies could verify and expand the findings of the present research on expert teachers beliefs and practices of technology-enhanced creativity development using both qualitative or quantitative methodologies, targeting regular teacher groups, different education levels, and areas of the curriculum.
- Future studies could also examine the technology-based instructional approaches valued and implemented by technology-integration expert secondary school teachers in this study and less targeted by previous research. More specifically: (1) the effects of various levels of technology access on K-12 students' creative ideation and production; (2) the effectiveness and conditions of using commercially available simulations, knowledge engines, and microworlds during inquiry-based learning and problem-solving on students' creativity in STEM areas; (3) the implementation possibilities and effectiveness of subject-related commercial video games on students' domain-specific creativity development and learning; (4) the effects and conditions of producing diverse digital products focused on students' creativity and learning in both subject-specific and cross-curricular domains; (5) the effects and conditions of diverse purposes and audiences enabled by technology on students' creative production and learning; (6) the effects and conditions of technology enabled co-creation in face-to-face, blended, and online environments on student' creativity and learning; (7) the feasibility of promoting creativity through online and blended environments in K-12 settings.

Policy, teacher education, and research focused on these areas could improve the effectiveness of technology-enabled creativity enhancement for all students in secondary schools.

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CRediT authorship contribution statement

Enikő Orsolya Bereczki: Conceptualization, Methodology, Formal analysis, Investigation, Data curation, Writing - original draft, Visualization, Project administration, Funding acquisition. **Andrea Kárpáti:** Conceptualization, Methodology, Validation, Writing - review & editing, Supervision, Funding acquisition.

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Appendix A. General overview of the observed lessons

Participants	Context	Physical environment	Summary of observed lessons
Anita (EFL1) 11 students	11th grade EFL Advanced elective course Topic: Speculating about people and places Duration: 45′	Regular classroom, horseshoe seating plan Student mobile phones (one/ student) Photo capturing and sound recording tool, *Facebook* group, email	First, students learnt language related to speculating about past events through personalized tasks, then practiced using the new language in pairs. **They then, either individually or in pairs, took photos with their mobile phones in the schools' common areas to use them as prompts for speculation.** Each student shared their photo with another student, who then speculated about where the photo could have been taken. **These monologues were recorded and sent back to the student who took the photo and the teacher for feedback on ideas and accuracy.** Students could choose the tools they wanted to use to share photos and voice recordings with each other.
Susan (EFL2) 14 students	9th grade EFL Regular class Topic: Culture -English speaking countries (Review) Duration: 45′	Regular classroom, horseshoe seating plan Teacher laptop, LCD projector Student mobile phones (one/ student) *Kahoot!*	**Students in groups of three played *Kahoot!* trivia quizzes they created at home**. Questions were based on what had been studied during the semester and on students' self-directed Internet-based research findings. Quiz categories had been chosen by groups. **One student from each group presented and moderated the "quiz show", while others played and competed using one mobile phone per group.** Before each quiz students shared handouts created by them with information to help answer quiz questions for peers. After playing each quiz, students and teacher gave verbal feedback to quiz questions based on quality and language accuracy criteria, and reflected whether it was engaging to play the quiz. Students would continue to present and play more quizzes in the next class.
Martha (HUN1) 14 students	11th grade literature Advanced elective course Topic: Symbolist poems Duration: 90′	Part 1 Computer lab, horseshoe seating plan Teacher desktop computer, LCD projector Student desktop computers (one/ group) *MS Movie Maker* Part 2 Common areas in school, street, park, classroom Teacher laptop Student mobiles phones Photo, video, and sound capturing tools	During these two lessons students created poetry videos in small groups. Part 1: After introducing the task, **the teacher played an inspiring poem video to students, which was followed by a whole group discussion of what constitutes a quality poem video**. The teachers also highlighted some features of the video editing software students could use to produce their clips. **Students then chose a Symbolist poem, scripted their videos, left the classroom, and worked in common areas or outside the school to record sound, and moving images using their mobile phones.** Part 2: Students returned to the classroom and played their audio and video recordings to the teacher and others. Some groups revised their work based on the feedback they received. **The poem videos were to be edited during the next class in the computer lab and presented and critiqued by peers and teacher**.
Judith (HUN2)	11th grade Hungarian literature	Computer lab, traditional seating plan	Part 1: Students accessed a *RealtimeBoard* with the tasks for the class and links to online sources through desktop computers in the lab. Students first solved an interactive exercise in *LearningApps* matching famous quotations from the play with major themes, which was then checked and discussed as a whole group. Student pairs were then asked

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(*continued*)

Participants	Context	Physical environment	Summary of observed lessons
13 students	Regular class Topic: The Tragedy of Man (Hungarian play published in 1861) Duration: 90′	Teacher desktop computer, LCD projector Student desktop computers (one/student) *RealtimeBoard, Doodle LearningApps, Google Docs & Drive*	to choose a theme and identify related problems using the online sources the teacher shared with them through *RealtimeBoard.* Problems were discussed as a whole class. Part 2: Students in pairs chose a scene from Tragedy of Man in and were asked **to write collaboratively a synopsis and screenplay, setting the chosen scene in modern times using shared *Google Docs*. Students used the resources shared by the teacher on *RealtimeBoard*. Teacher monitored students' collaborative writing in *GoogleDocs*. Synopsis and screenplays were shared with and critiqued by other groups by adding comments and questions in *GoogleDocs***.
Bill (MAT1) 10 students	11th grade maths Advanced elective course Topic: analytic geometry equations Duration: 45′	Regular classroom, traditional seating plan Teacher laptop, LCD projector Student mobile phones *Kahoot!, GeoGebra, WolframAlpha*	Students solved mathematical problems related to analytic geometry equations. Students played a teacher-created mathematical *Kahoot!* maths quiz individually using their own mobile phones. **Students used *WolframAlpha* or *Geogebra* to explore their ideas and find answers to quiz questions.** Solutions were discussed as a whole group after each question. **The quiz was moderated by the teacher who asked several open-ended questions, which were answered by students willing to do so**.
Rose (MAT2) 13 students	9th grade maths Regular class Topic: inequalities (Review) Duration: 45′	Regular classroom, traditional seating plan Teacher desktop computer, Interactive Whiteboard *PowerPoint, Popplet, CrosswordLabs*	In this review lesson students were first asked to brainstorm mathematical concepts of inequalities in pairs. Concepts were to be categorized using *Popplet* at the Interactive Whiteboard. This was not possible due to technical problems. **The teacher then presented a *PowerPoint* presentation containing optical illusions, and students were asked to recognize and discuss the type of inequalities represented by each image first in pairs, then in whole group**. Students then solved inequality problems. **As an optional task, students could create a mindmap in *Popplet* or a crossword puzzle in *CrosswordLabs* of the reviewed concepts as homework**, **and were asked to share these in the class *Facebook* group**.
Ada (SCI1) 28 students	9th grade Regular class Project week Topic: motion (Review) Duration: 180′	Physics lab (group pods), hall, meeting room (group pods) Teacher desktop computer Student laptops (2/group) Student mobiles phones *Lego* robots, *Micro:bit, OneNote, LabCamera, Lego Mindstorms*	Students solved problems and challenges using their knowledge in physics and mathematics in small groups. **Each group had a *OneNote* shared notebook for planning and documenting group work**. Students could choose from seven problems or challenges: 1. Build a functioning toy car using 3D printed elements. **2.Build the fastest solar power fuelled toy car.** 3. Construct a parachute that will deliver an egg safely to the ground when dropped. 4**. Organize a *Lego* robot race in the group and create a video of it.** 5. Build a toy sailboat. 5. Build a paddleboat. **Students used their mobile phones and *LabCamera* on their laptops to collect and analyse data, and refined their ideas based on the findings**. Also, students were asked to take photos, create videos and written explanations of their solutions to these tasks. **Outcomes would be presented and evaluated by teacher and peers based on rubrics at the end of the project week**.
Boris (SOC1) 29 students	9th grade history Regular class Topic: The Middle Ages (Review) Duration: 45′	Regular classroom, traditional seating plan Teacher laptop, LCD projector *Plickers*	After discussing the homework, **students played a teacher-created and moderated *Plickers* quiz individually. After each question, possible answers were discussed as a whole group. Teacher also asked several open-ended questions, while students willing to answer answered them**. At the end of the lesson, teacher announced the winners of the quiz.
Elisabeth (SOC2) 25 students	8th grade history Regular class Topic: Introduction to Napoleonic Era Duration: 85′	Regular classroom, group pods Teacher laptop, Interactive Whiteboard Student laptops (1/student) *OneNote, PowerPoint, LearningApps, YouTube*	At the beginning of the class **students presented the infographics they had created in pairs on the French Revolution, and received short verbal feedback on their accuracy and design from teacher and peers.** Students in pairs or groups solved two teacher-created interactive exercises in *LearningApps* which served as an introduction to the new topic. After a teacher-created *PowerPoint* presentation on Napoleon, students were asked to watch a short documentary and answer related questions. Students worked on this task in groups in the classroom and in the hall. **After a whole class discussion, students were asked to imagine what they would need to do to become the ruler of Europe if they were a young Napoleon. They used *OneNote* to take collaborative notes and did online research.** Students would continue to work on this task the next class.
Robert (ART1) 33 students	10th grade art history Regular class Topic: Leonardo da Vinci Duration: 45′	Regular classroom, traditional seating plan Teacher laptop, Interactive Whiteboard Student mobile phones (1/per pair) QR reader	After recognizing paintings hidden behind *QR* codes using their mobile phones and brainstorming about Leonardo da Vinci, students took part in an interactive lecture. **The lecture was supported by a teacher-created *presentation* featuring da Vinci's paintings as well as several pop cultural references to his work.** During the presentation, the teacher asked several open-ended questions. Students then interpreted paintings in pairs and discussed interpretations as a whole

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Participants	Context	Physical environment	Summary of observed lessons
			class. At the end of the lesson, **students were asked to create a digital reinvention of one of da Vinci's works as homework**.
Zoey (ART2)	10^{th} grade visual culture Regular class Topic: Renaissance, reinventions of masterpieces	Art room, traditional seating plan Teacher laptop Interactive Whiteboard Student mobile phones	This class started with a teacher-created and moderated *Kahoot!* review quiz in which students competed individually using their own mobile phones. The teacher told students that they were going to create a paraphrase of one of da Vinci's masterpieces. The teacher shared with students the link to a *LearningApps* matching game. Students worked in groups and matched the reinventions with the original pieces using their mobile phones. **The teacher shared 11 famous Mona Lisa paraphrases with students in *Google Drive* who then discussed the artistic technique, period, and style used in each. Students brainstormed ideas to create new reinventions and searched the Internet on their mobile phones to develop ideas. Students could choose to create either a digital or an analogue image. The task was completed as homework**.
24 students	Duration: 45′	*Kahoot!, LearningApps, Google Drive*	

Note. The technology-based activities related to fostering creativity indicated by teachers in the pre-observation interviews are bolded.

Appendix B. General information about the collected documents

Pseudonym	Document abbreviation	Characteristics	Type
Anita (EFL1)	D1	extant, private, full access, electronic, text	Lesson plan
Susan (EFL2)	D1	extant, private, full access, paper-based, text and images	Student-created handouts
Martha (HUN1)	D1	original, public, partial access, online, multimedia	Teacher website featuring project descriptions and student work
Judith (HUN2)	D1	original, public, full access, electronic, online and downloadable, text and hyperlinks	Project plan
Bill (MAT 1)	D1	original, public, full access, electronic, online and downloadable, text and hyperlinks	best practice blog
Rose (MAT2)	D1	original, private, full access, electronic, text and hyperlinks	Unit plan
	D2	original, private, full access, electronic, text and hyperlinks	Project plan
	D3	extant, private, full access, electronic, text	Lesson plan
Ada (SCI1)	D1	original, public, full access, online, text and hyperlinks	Project plan
	D2	original, public, full access, online, text and hyperlinks	Project plan
	D3	original, private, full access, online, multimedia	Students' project portfolio
Albert (SCI1)	D1	original, public, full access, online, text and hyperlinks	Project plan
Elisabeth (SOC1)	D1	original, public, full access, online, multimedia	School website featuring project descriptions and student work
Boris (SOC2)	D1	original, public, full access, electronic, online and downloadable, text and hyperlinks	Project plan
Robert (ART1)	D1	extant, private, full access, paper-based, text and images	Teacher-created handouts
Zoey (ART2)	D1	original, public, full access, electronic, online and downloadable, text and hyperlinks	Project plan

Appendix C. Coding analysis of the interview transcripts with reference to teachers' beliefs about creativity

Category	Theme	Subtheme	Nr. of resp.	Comment frequency by respondents												Total com.
				ART1	ART2	EFL1	EFL2	HUN1	HUN2	MAT1	MAT2	SC I1	SC I2	SOC1	SOC2	
	Means originality		**12**	1	2	2	1	1	3	2	1	2	1	2	2	**20**
	Means appropriateness		**12**	1	2	2	1	1	2	1	1	1	1	1	2	**15**
		Curiosity	**9**	0	2	2	1	1	0	2	1	1	1	1	0	**12**
		Knowledge	**7**	2	2	0	1	0	0	0	2	0	1	2	1	**11**
DEFINITION	Requires certain personal characteristics	*Hard work and commitment*	**7**	0	1	1	0	0	2	2	0	2	1	1	0	**10**
		Risk-taking	**7**	0	1	1	1	1	0	1	0	0	1	0	1	**7**
		Intrinsic motivation	**5**	1	1	0	0	0	0	0	1	0	0	1	1	**5**
	Requires certain environmental conditions	*Idea time*	**11**	1	2	2	1	0	1	1	1	1	1	2	2	**28**
		Safety and trust	**6**	0	0	5	1	2	0	0	3	3	0	0	2	**16**

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Category	Theme	Subtheme	Nr. of resp.	Comment frequency by respondents												Total com.
				ART1	ART2	EFL1	EFL2	HUN1	HUN2	MAT1	MAT2	SC I1	SC I2	SOC1	SOC2	
		Freedom	**9**	1	1	2	1	3	1	1	1	0	1	0	0	**12**
		Constrains	**6**	0	1	3	1	2	1	0	0	0	1	0	0	**9**
	Easy to find in the art-related subjects		**6**	1	0	2	0	1	0	0	1	1	0	0	1	**7**
	Relevant in all curricular areas		**12**	1	3	2	2	2	1	1	1	4	2	2	1	**22**
SPECIFICITY	Specific to each curricular area		**12**	4	1	4	2	7	7	6	9	6	2	2	4	**54**
	Multiple creativities manifest in one curricula area (e.g. scientific, artistic, language)		**6**	1	0	0	1	1	0	0	0	3	1	1	0	**8**
	Changes across education levels		**10**	2	0	2	0	3	6	3	1	6	7	2	3	**35**
MALLEABILITY	Can be nurtured		**12**	1	1	1	1	1	1	1	2	1	1	1	1	**13**
	Is difficult to assess		**6**	0	0	1	1	3	2	2	0	0	0	1	0	**10**
	Respondents comments total			**15**	**25**	**30**	**16**	**28**	**27**	**23**	**24**	**31**	**23**	**23**	**19**	**284**

Appendix D. Coding analysis of the interview transcripts with reference to teachers' beliefs about nurturing creativity with technology

Theme	Nr. of resp.	Comment frequency by respondents												Total com.
		ART1	ART2	EFL1	EFL2	HUN1	HUN2	MAT1	MAT2	SCI1	SCI2	SOC1	SOC2	
Igniting creativity with technology	8	1	1	4	0	1	0	1	0	0	1	3	1	13
Developing ideas with technology	8	0	1	0	0	2	0	2	2	7	6	1	1	22
Creating with technology	11	2	7	4	3	6	14	0	3	9	1	3	4	56
Collaborating with technology	8	0	2	1	1	1	2	0	1	1	0	0	3	12
Scaffolding creativity with technology	10	1	2	3	2	0	2	1	1	5	1	0	1	19
Communicating and evaluating creativity with technology	9	2	2	3	1	3	6	0	2	2	0	0	3	24
Respondents comments total		6	15	15	7	13	24	4	9	24	9	7	13	146

Appendix E. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.tsc.2021.100791.

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