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A conceptual impact model of digital support for student self-regulation and emotion regulation grounded in Self-Determination Theory

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Abstract
We present a conceptual impact model illustrating how digital tools can facilitate the fulfillment of basic psychological needs, autonomy, competence and relatedness, which in turn may foster improvements in self-regulation and emotion regulation. The model incorporates features of digital tools such as personalized learning paths, real-time feedback mechanisms, progress tracking, reward systems, gamification, targeted interventions and community support, illustrating how these elements address one or more basic psychological needs. These are further complemented by AI-specific mechanisms such as adaptivity, intelligent feedback and automated social presence. The model demonstrates that fulfilling the need for competence and autonomy may influence self-regulation, while relatedness - emotion regulation, which can consequently enhance mental health. Learner traits, such as computational thinking abilities, alongside contextual factors like technical infrastructure, shape how students engage with and benefit from digital tools. The claims and future directions are discussed.

Keywords Digital tools, Self-determination theory, Basic psychological needs, Impact model

1 Introduction

The COVID-19 pandemic accelerated the shift toward flexible, digital educational approaches designed to address the complexities of contemporary society [1], opening new avenues for both knowledge acquisition and sharing [2]. The integration of digital tools has broadened access to personalized learning experiences, fostering greater learner engagement [3] and supporting more autonomous, student-driven curricula [4]. Notably, digital tools offer a distinctive ability to blend entertainment, education and the cultivation of social skills, as demonstrated by the use of serious games (e.g. [5]).

Recognizing the critical role of digital tools in modern education and the necessity of fulfilling the fundamental psychological needs of autonomy, competence and

relatedness, as delineated by Self-Determination Theory [6–9], this article endeavors to systematically synthesize and elucidate the diverse functions and psychological impacts of such tools. This manuscript proposes a conceptual impact model that maps specific features of digital learning tools, including those supported by Artificial Intelligence (AI), to the fulfillment of basic psychological needs, offering a new perspective on how technology can influence learner overall well-being. While Self-Determination Theory provides a well-established framework for understanding need satisfaction in general learning contexts, this model addresses the digital learning environment, highlighting how features create new pathways for need fulfillment that are not present in traditional analog settings. This focus on the interplay between digital tool affordances and psychological needs offers novel insights for designing technology-enhanced learning experiences.

2 Basic psychological needs

The fulfillment of basic psychological needs - autonomy, competence and relatedness - is essential for intrinsic motivation, well-being [8] and a heightened sense of vitality [10]. Self-Determination Theory conceptualizes the self as an active process [11], in which psychological needs emerge early in development and are constantly shaped by the environment, most effectively supported within nurturing social contexts [12].

The need for autonomy is framed as the experience of self-endorsement, wherein individuals perceive their actions as congruent with their values [8, 13]. Competence refers to the perception of effectiveness in one's interactions with the environment and the ability to achieve intended outcomes and to stay persistent [8, 14]. Relatedness, defined as the experience of social connections and a sense of belonging [8], has been shown to enhance student engagement [15], academic performance [16] and feelings of warmth [17], whereas conflict in teacher-student relationships is associated with poorer mental health [18].

The satisfaction of autonomy, relatedness and competence underpins optimal psychological functioning, transcending cultural boundaries and individual need intensity, while their frustration correlates with maladaptive outcomes such as self-doubt [19] or the growth of negative attitudes toward learning [20]. Research underscores the important role of teachers in supporting students' basic psychological needs (e.g. [21]) with digital innovation simultaneously reshaping the foundations of the education system [22].

3 Digital learning

Digital learning refers to the use of Information and Communication Technology (ICT) to deliver interactive educational experiences [22]). A digital tool may be an application, computer program, website or electronic device designed to facilitate tasks through the use of digital technology, incorporating audio and visual stimuli (e.g. [23]). According to Viberg et al. [24] (p. 234), these tools "are artifacts designed to support humans in various activities". All digital tools share a set of common characteristics, with task structure and personalization identified as key features contributing to educational effectiveness [25]. Digital tools facilitate access to resources [26], promote the development of self-regulatory skills (e.g. [27]) and enhance emotion regulation (e.g. [28]) although excessive use may elicit negative emotional states [29] and diminished critical thinking abilities

[30]. Highly beneficial use of digital tools in education relies on teachers possessing strong pedagogical and technological skills [31], as well as effective integration strategies [32]. Similarly, students with special needs in emotional and social development may benefit from digital tools [33, 34]; however, the outcomes depend on the appropriate selection of such tools [35]. To fully realize this potential, educational technologies can integrate modern AI-specific mechanisms such as adaptive assessment [36], that extend beyond basic personalization through dynamic adaptation to learner input. Differentiation between static digital tools and dynamic AI-driven systems is fundamental to understanding their respective roles in education, as dynamic systems are able to adapt in real-time and deliver continuous feedback (e.g. [37]), thus wholly supporting personalized learning.

3.1 Personalized learning paths

The adaptability of digital tools facilitates personalized instructional approaches [38], enabling alignment of educational materials with students' cognitive processing patterns [39] through the already mentioned use of AI (e.g. [40]) and data analytics [41]. The continuous evolution of digital tools underscores their potential to change educational paradigms [42], shifting from a one-size-fits-all approach toward a more individualized, data-informed model [43].

3.2 Progress tracking and reward systems

Real-time feedback mechanisms [44], such as automated error correction [45] or reward-based systems like strategic point allocation [46], have been shown to significantly influence learners' self-perception [47]. At the same time, learner autonomy is crucial, as it fosters self-regulated learning behaviors and intrinsic motivation, which are key components of cognitive development [48]. The interplay between feedback and autonomy-supportive environments underscores the importance of designing digital tools that guide learners while also empowering them to take ownership of their educational journeys, such as with the use of formative assessment apps, e.g., "Kahoot!".

3.3 Gamification

Gamification, defined as the integration of game-based elements into non-game contexts (e.g. [49]) has emerged as an effective pedagogical strategy, contributing to improved student proactivity and knowledge retention [50]. This technique enhances motivation, making learning more engaging through satisfaction of needs for competence, autonomy and relatedness [51, 52]. Moreover, gamification promotes a positive educational culture, where errors are considered a natural part of a learning process [53] ("freedom to make mistakes", p. 17). A well-known example of a gamified tool is "Duolingo", an app for learning languages that consists of short and easy to navigate lessons.

3.4 Interventions

Technology-enhanced interventions have been shown to optimize students' outcomes in mathematics and literacy [54]. Further, app-based interventions have demonstrated efficacy in promoting self-regulation [55], while working memory training has been associated with improvements in emotion regulation [56]. Emotional outcomes may also be

effectively supported through annotator tools [57] or smartphone-based resilience interventions, such as the "JoyPop app" [58].

3.5 Community support

Digital tools facilitate user interaction, fostering collaborative environments and promoting sustained participation [59]. Community-driven features, such as online discussion forums [60] and peer feedback mechanisms [61], can strengthen students' sense of belonging. According to Kipkosgei et al. [62], knowledge exchange not only builds relationships but also helps reduce feelings of isolation. A notable tool example is the "Ehky App", which allows users to build a virtual community.

The selection of evidence was guided by its direct relevance to the core premises of the proposed model, with priority given to methodologically rigorous and contemporary studies that specifically investigate the impact of digital learning tools on the satisfaction of basic psychological needs within the context of student self-regulation and emotion regulation. Studies that did not align closely with these criteria were excluded to ensure a focused and coherent theoretical argumentation. Drawing on both theoretical frameworks and empirical studies, we formulated four claims regarding the functional roles of digital tools.

3.6 Claim 1: digital tools enhance basic psychological needs satisfaction

3.6.1 Autonomy

Supporting autonomy involves providing choices within limits [63]. Online learning environments allow students to decide when and where they study, which offers greater flexibility [64] and reduces the pressure associated with deadlines [65]. However, technology can both support and undermine autonomy: some tools foster it through non-controlling language [66], while others diminish it, manipulating behavior [67] or using controlling incentives [9]. Understanding the mechanisms through which technological systems either support or erode autonomy is crucial for design considerations in student-technology interactions.

3.6.2 Competence

Digital tools can enhance students' perception of their own competence [68], for instance through the use of gamified elements such as badges [69]. Receiving immediate feedback, whether through computerized quizzes, automated instructor comments, online peer input [70] or a quest map showing points, can enhance the fulfillment of the need for competence by helping students track their progress [66]. Moreover, online courses that incorporate instructional guidance [71] have been shown to enhance students' effective cognitive processing.

3.6.3 Relatedness

Performance-sharing features such as leaderboards [72], along with interactive communication tools [73], can enhance group cohesion and social connectedness, thereby supporting the need for relatedness. This need can also be addressed through cooperative learning strategies implemented by teachers within digital learning environments [74], thus providing structured opportunities for peer interaction [75]. Group projects and

assessment strategies that prioritize growth over judgment [76] may cultivate collaboration, even across different locations [77].

Basic psychological needs in digital environments are intricately intertwined with traditional educational practices, all of which can either support or impede need satisfaction. For example, attributional training that encourages students to link success to effort can enhance their sense of competence, while supportive teacher-student relationships [78] are pivotal in promoting a sense of relatedness. Importantly, digitalization offers new avenues to enhance – rather than replace – the established methods. The impact of digital tools is largely determined by the extent to which they achieve balance between innovation and traditional pedagogical approaches [79].

3.7 Claim 2: digital tools foster self-regulation growth

Self-regulation, a fundamental competence for human agency [80], is a complex skill that enables individuals to adapt their behavior to the cognitive, emotional and social demands of a situation given, in a way that serves their long-term interests [81, 82]. This competence, characterized as "more conscious than unconscious" [83] (p. 49), undergoes continuous development from early childhood [84], represents a key resilience factor [85] and plays a crucial role in promoting mental and physical health (e.g. [86]). Self-regulation may be internalized in culturally specific ways, shaped by practices and values prevalent within different societies [87].

Digital tools can promote self-regulation, supporting self-monitoring [88], for example through the use of automated feedback systems [89], metacognitive and motivational regulation prompts [90] or self-paced learning environments [91]. Ng et al. [92] demonstrated that ChatGPT-enhanced tutoring systems support students' self-regulated learning, facilitating metacognitive processes through adaptive guidance. The flexibility of digital tools allows students to take charge of their learning; however, technologies might also lead to a loss of self-regulation skills, making learners overly reliant on the system's feedback [93]. This effect on self-regulation parallels the influence of autonomy and competence, suggesting that supporting these needs also facilitates the development of self-regulatory capacities. Self-regulated learning persists as long as learners maintain control over their goals, strategies and monitoring, even when digital tools offer scaffolding (e.g. [94]). External prompts or adaptive guidance serve not to replace but to enable or enhance self-regulatory processes, particularly for those still developing these skills.

3.8 Claim 3: digital tools foster emotion regulation growth

According to Gross [95, 96], emotion regulation refers to the cognitive processes individuals use to modulate their emotional responses, which contributes to improved well-being [97], better mental health outcomes [98–100] and is essential for effective cognitive information processing [101]. Poor emotion regulation has been associated with a higher risk of anxiety disorders [102] and maladaptive behaviors [103].

Satisfaction of the need for relatedness, may facilitate adaptive emotion regulation [104]. In this context, digital tools may incorporate social skills training [105], assess psychological states [106], foster interpersonal abilities [107], deliver mental health interventions [108, 109] and assist in identifying emotions [110]. Furthermore, digital interventions have been validated as effective means of mitigating digital addiction [111] and both preventing and treating depressive disorders [112], as exemplified by the

mobile-based intervention "StudiCare Mindfulness", which has shown efficacy in alleviating depressive symptoms [113].

3.9 Claim 4: the impact of digital tools is moderated by contextual factors and student characteristics

3.9.1 Context

Digital tools' impact is contingent upon the contextual factors in which they are deployed, including variables such as the differentiation between formal and non-formal educational environments [114]. In formal educational contexts, the effectiveness of digital tools may be enhanced by teacher guidance, whereas in non-formal settings, learner autonomy and interest play a crucial role. In a recent qualitative study [115], secondary school students expressed a preference for traditional study methods when preparing for exams in formal education, while favoring digital tools for exploring their personal interests.

3.9.2 Tool quality and stable internet

The effectiveness of digital tools is contingent upon their overall quality, which encompasses a range of factors including user-friendly interface design [116], capturing of students' cognitive load [117], technical functionality and the reliability of the educational content. In contrast, suboptimally designed tools, characterized by unreliable functionalities, can impede the learning process, resulting in student disengagement [56]. Additionally, inaccurate or misleading content can generate misconceptions and obstruct students' ability to acquire accurate knowledge [118].

Stable internet connectivity is fundamental for maximizing the potential of digital tools, as disruptions restrict access to resources, exacerbate educational disparities [119] and compromise the ideal of learning anytime and anywhere [120]. Deficiencies in infrastructure also shape teachers' perceptions of digital tools, hindering their integration into pedagogical practices [121].

3.9.3 User traits

The ability to benefit from digital tools is influenced by a range of individual factors, including students' computational thinking skills [122], self-regulation, motivation and technical competencies [123], as well as their interest [124], cultural and social background [125], developmental stage [126] and gender [127]. For instance, female students demonstrate more cautious engagement with tutoring systems compared to non-female peers [128].

3.9.4 Ethical issues

Ethical considerations surrounding the use of digital tools significantly influence their effectiveness, as concerns related to privacy, transparency and fairness can impact learners' trust, willingness to engage and their overall acceptance of the technology. Ensuring ethical integrity in the design and application of educational technologies can also promote a more inclusive earning environment [129].

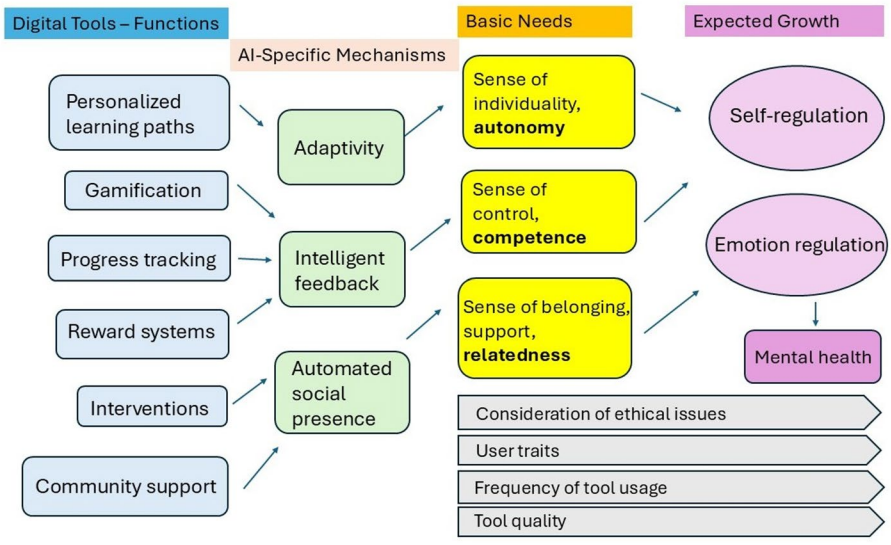

Fig. 1 A conceptual impact model of digital tools. A diagram shows how digital tool features support basic needs, which in turn foster personal growth outcomes. On the left, six key features of digital tools are listed: personalized learning paths, gamification, progress tracking, reward systems, interventions and community support. Arrows connect each feature to different basic human needs. From these needs, arrows extend to the right, indicating the expected growth in self-regulation, emotional regulation and mental health. At the bottom of the diagram, arrows represent moderating factors - consideration of ethical issues, user traits, frequency of tool usage and tool quality. The model also includes AI-specific mechanisms: adaptivity, intelligent feedback and automated social presence that are situated between digital tools and basic needs

3.9.5 A model

An impact model serves as a framework outlining the causal pathways through which inputs lead to outcomes [130]; in this article, we propose an integrated conceptual model that demonstrates how digital tools can impact the fulfillment of basic psychological needs while supporting self-regulation, emotion regulation and overall mental health (Fig. 1). This model represents a holistic approach by integrating key elements such as personalized learning, adaptive content delivery, gamification, reward systems and community-driven features, which are presented as exemplary and open to broad interpretation, without excluding the possibility that other attributes may be similarly effective. Over time, as tool usage extends [131] and accompanied by improving tool quality, supportive user traits and the consideration of ethical issues, the impact on basic psychological needs can foster improvements in self-regulation and emotion regulation. Further, learner characteristics such as digital literacy, self-regulation skills and motivational orientation are expected to moderate the impact of specific digital tool functions on need satisfaction. For example, learners with higher self-regulatory capacity may benefit more from tools offering adaptive feedback or progress tracking. Similarly, the frequency and quality of digital tool use are likely to influence outcomes, as occasional interactions may be insufficient to elicit psychological effects, whereas sustained engagement can more robustly enhance the satisfaction of basic psychological needs. The proposed model incorporates also several AI-specific mechanisms to improve educational outcomes: adaptivity enables the system to tailor instructional content dynamically based on individual learner performance and preferences; intelligent feedback provides timely, context-sensitive responses that guide learners through challenges and

automated social presence (e.g. [132, 133]), fosters a sense of engagement by simulating human-like communication.

4 Summary and conclusions

The proposed model is founded on four claims: each grounded in prior research within the field of digital learning. First, we posit that digital tools can support the fulfillment of the needs of autonomy, competence and relatedness over sustained periods. Secondly, we argue that digital tools play a pivotal role in facilitating self-regulation by supporting students' needs for autonomy and competence. Digital tools offer adaptive learning pathways that enhance learners' sense of control, while fostering autonomy, competence and self-regulation skills. Thirdly, we claim that digital tools have the potential to enhance students' emotion regulation by supporting their need for relatedness. When designed to promote social connections, such as through access to peer networks, these tools can enhance a sense of belonging, which in turn fosters more adaptive emotional responses and reduces negative affective states. Finally, we assert that the effectiveness of digital tools is contingent upon the specific contextual conditions of their use, as illustrated in the model through user traits, frequency of tool usage, consideration of ethical issues and tool quality. Grounded in these claims, the model presents a comprehensive framework for rethinking the effectiveness of digital tools in educational contexts, emphasizing their facilitative role rather than assuming an inherent capacity to enhance need satisfaction.

5 Limitations and future directions

The article has several limitations. Firstly, the generalizability of the proposed model is limited. The findings that inform the model are derived from specific contexts, which may not be applicable across all educational settings or learner groups. The proposed framework is intended as a heuristic aimed at guiding future research by identifying key variables and hypothesized relationships that may influence the satisfaction of basic psychological needs in digital learning environments. While Self-Determination Theory differentiates between the basic psychological needs for autonomy, competence and relatedness, it is increasingly evident that specific need-supportive actions often fulfill more than one need simultaneously. For example, feedback not only contributes to perceived competence by offering task-related information but may also support relatedness, particularly when it conveys a sense of shared struggle among peers or fosters connection with the teacher. This overlap is reflected in several empirical studies using student questionnaires on teacher behaviors, where items intended to capture distinct needs often load onto a single factor (e.g. [134–136]). Similarly, in established frameworks such as the TARGET model, various dimensions of need support are often conceptually and empirically intertwined [137]. Such convergence may partly stem from theoretical overlap within the Self-Determination Theory framework, but it may also point to the inherently complex nature of need-supportive interactions. This complexity could be even more pronounced in the context of digital learning tools, where social cues and contextual nuances are reduced or abstracted. Furthermore, as new digital tools emerge, the model may require adaptation to accommodate novel technologies [138].

A further limitation lies in the absence of longitudinal data substantiating the sustained impact of digital tools on basic psychological needs, as the model predominantly

draws on studies reporting short-term outcomes. A longitudinal cohort study (e.g. [139] could systematically track a defined group of students and teachers over an extended period, capturing the dynamic integration of digital tools into instructional practices and assessing corresponding impacts. In addition, the measurement of psychological outcomes is not fully addressed in the article. While the proposed model highlights the potential positive effects of digital tools, it does not provide methodologies or metrics for assessing these outcomes. Standardized tools such as the Student Engagement Scale study (e.g. [140]), could be used in a pre-post intervention design to measure students' emotional responses before and after deploying digital tools. To empirically validate the contributions of digital, particularly AI-supported, interventions (e.g. [141]), a multimethod research design is recommended, whereby randomized controlled trials could compare outcomes between students receiving AI-supported interventions (e.g., adaptive feedback) and those using standard digital tools. Process-oriented measures, such as log-based process data (e.g. [142]) may capture how learners interact with adaptive features and respond to personalized feedback. Experience sampling methods and post-task surveys may help evaluate perceived social presence and emotional support provided by conversational agents. Structural equation modeling or multilevel modeling could further clarify the mediating role of psychological needs satisfaction within Self-Determination Theory frameworks.

Although the model acknowledges contextual factors, it underestimates the essential contribution of teachers. Teachers' self-efficacy [143], their competence [144] and attitudes toward the use of digital technologies [145] play a pivotal role in a successful tool integration. Teachers who view digital tools as beneficial are more likely to participate in professional development aimed at enhancing digital competencies [146], and such structured training plays a crucial role within educational institutions [147].

Finally, the model could be further refined by incorporating guidelines to address ethical challenges, ensuring that the implementation of digital tools respects data privacy [148], prevents surveillance [149], discourages addictive use [150], mitigates cybersecurity risks [151] and supports sustainability [152]. Without consideration of these factors, the model risks presenting only a partial understanding of the impact of digital tools. It could overestimate the positive effects or miss out on negative consequences that might arise from digital tool usage, like increased screen time contributing to social isolation [153] and to mental health problems [154]. The growing integration of AI into educational technologies also calls for increased attention to ethical and social concerns, including privacy protection (e.g. [155]) the mitigation of algorithmic bias (e.g. [156]) and the prevention of user dependency (e.g. [157]). Integrating ethical principles and transparency at the core of AI implementation ensures responsible innovation and supports a relationship between technological advancement, the respectful treatment of all learners (e.g. [158]) and the impact of AI in educational tools on climate change due to its large energy requirements.

The model delineates potential mechanisms by which digital tool functions may provide supplementary support for basic psychological needs and recognizes that these effects are likely moderated by key contextual and individual variables, thereby underscoring the necessity for future research to examine the specific conditions, learner profiles and educational settings in which such functions facilitate or impede need satisfaction. This research seeks to inform the development of evidence-based strategies

that utilize digital tools and, additionally, AI technologies to support basic psychological needs while also fostering student self-regulation, emotion regulation and mental health.

Author contributions
All authors have accepted responsibility for the content of this manuscript, consented to its submission to the journal, reviewed the results, and approved the final version. A.S. conducted the analysis, performed the literature review, developed the model, and drafted the original manuscript. C.R. and G.C. contributed to the revision and the overall structure of the manuscript. S.D.S. and P.D.E. participated in the review of the original manuscript.

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Data availability
We do not analyse or generate any datasets, because our work proceeds within a theoretical approach. One can obtain the relevant materials from the references below.

Declarations

Ethics approval and consent to participate
Not applicable.

Consent for publication
Not applicable. This study is conceptual in nature and does not involve any human participants. Consequently, no informed consent was required.

Competing interests
The authors declare no competing interests.

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