AI Applications in Vitagen-Based Education: Expanding Opportunities and Emerging Risks in Developing Students' Mentality

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Abstract: Vitagen-based education treats learning not only as the acquisition of disciplinary knowledge, but as the deliberate cultivation of students' mentality – a constellation of metacognitive, self-regulatory, motivational, and socio-emotional dispositions that shape how individuals relate to themselves, others, and a rapidly changing world. This article explores how artificial intelligence (AI) can both strengthen and destabilise this project. First, it reconstructs the theoretical foundations of vitagen-based education and clarifies the notion of mentality in relation to agency, reflection, and lifelong learning. It then maps four major clusters of AI applications – personalisation and adaptive pathways, intelligent mentoring and feedback, assessment and data-informed insights, and learning analytics for mentality development – showing how these tools can scaffold reflection, support growth mindset, and extend socio-emotional learning when carefully designed. At the same time, the article identifies four interlocking domains of risk: privacy and surveillance; bias, fairness, and inclusivity; dependency and erosion of critical thinking; and mental health and well-being. Drawing on international cases and longitudinal studies, the analysis distils pedagogical and policy implications for curriculum design, teacher professional development, and multi-level governance of AI in education. Finally, it outlines a research agenda for AI-enhanced vitagen education, arguing for ethically grounded, mixed-methods and cross-disciplinary inquiry. The article contends that AI will not automatically elevate vitagen-based education, but, under well-governed conditions, can become a powerful – though never neutral – partner in developing students' mentality.

Keywords: Vitagen-based education, artificial intelligence in education, mentality development, learning analytics, educational ethics.

1. INTRODUCTION

Education provides people with the tools to participate in society. Vitagen-based learning as a new pedagogical model not only enables the capacity building and efficiency of skills, attitudes and values, but also student mentalities. In this sense, attitude includes cognitive and non-cognitive aspects that comprise metacognition, self-regulation and socio-emotional attitudes (Xu, 2024). AI may have a role in increasing the efficacy and efficiency of vitagen-based education through cooperative learning, intelligent tutoring and mentoring, formative assessment, as well as learning analytics. These AI-enabled services can also enhance educators capacity of fostering students' mindset development and perhaps support whole-institution strategies (Schiff, 2021). Laying the ground for further explicit discussions of these applications, in this section a brief presentation is dedicated to vitagenbased education and the concept of mentality and how AI could act in such a framework. The outset outlines also key assumptions and terms.

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Vitagen education introduced by educator reformer Xuetao Xu, who outlined key parts of education as competency and mentality. Mentality We take inspiration from the nestlers section to formulate mentality, based on well-established theories of learning and cog- nition: the custom or habit one holds toward oneself, others, and towards a growing environment. In educational pedagogy, mentality refers to cognitive and non-cognitive characteristics such as metacognition, self-regulation and socio-emotional constructs. Vitagen education suggests that the mind is not static but an ever-developing entity which needs to be intentionally cultivated for the students' development. Applications of AI has the ability to enhance efficacy of pedagogical approaches emphasizing on students' mentality development, as there are tools used to disseminate vitagen-based education and teaching interactive learning and other competence-basedsubjects (Mollick and Mollick, 2023). In particular, AI can contribute to the goals of collaborative learning, intelligent mentoring, formative assessment and learning analytics mechanics that support educators in supporting students to expand their agency, metacognition and socio-emotional skills (Darling-Hammond 2019).

While vitagen-based education identifies a growing demand for mentality development nurtured by

contemporary curricula, such growth may still remain unrealised and warrants in-depth investigation. Consequently, this section first reviews existing theories of learning, cognition, and mentality development to establish a sound theoretical foundation for vitagen-based education, scrutinising the extent to which AI can influence learners' reflective practices and agency. The discussion subsequently advances to articulating the opportunities and risks associated with AI deployment, specifying the causal pathways and conditions under which those consequences may transpire.

2. THEORETICAL FOUNDATIONS OF VITAGEN-BASED EDUCATION

2.1. Conceptualizing Vitagens in Educational Contexts

To integrate artificial intelligence (AI) in education without compromising integrity, it is vital to establish relevant theoretical foundations. Such foundations generate foundational arguments, set epistemic parameters for constructing knowledge, and clarify the nature of AI-enhanced vitagen-based education. Preceding the core theoretical constructs, this section presents an overview of the argumentative structure and addresses anticipated critique against the rationale for AI integration. Vitagen-based education generates bids to AI from prevailing standards of similar pedagogical paradigms. The manner by which AI influences additional standards for enhancing reflective practice and extending learners' agency requires articulation. Identifying these mechanisms better positions educators to harness AI for augmenting mentality development.

2.2. Cognitive and Affective Implications for Learners

Experiencing profound public scrutiny from multiple quarters, AI warrants serious deliberation prior to any form of integration. Establishing and rigorously clarifying the theoretic grounds for embedding AI within vitagen-based education responds directly to these demands while simultaneously deepening the conceptual underpinning of both AI and associated pedagogical designs. Building on earlier treatments of agency and reflection, the theoretical basis elucidates specific AI provisions that influence agency and reflection. Each provision targets multiple pedagogical aims, yet supplementary guidelines help elucidate the relationship between mental development and AI applications within vitagen-based education. Consequently, by examining the pedagogical and theoretical motifs of agency and reflection, this section reiterates headway from personal to collective mentality whilst concurrently situating AI as techno-pedagogical provision for constructing an AIEd framework consistent with the aims of vitagen-based education.

3. AI-DRIVEN APPLICATIONS IN VITAGEN-BASED EDUCATION

AI-driven applications in vitagen-based education centre on intervention design, employing AI capabilities to collect data, generate insights, and offer personalised solutions across diverse learning scenarios. Developing students' mentality constitutes a primary goal. AI technologies facilitate effective, large-scale management of complex learning processes beyond individual human capability (Latif *et al*., 2023).

The first application area focuses on forming personalised, adaptive learning pathways aligned with conceptually targeted outcomes. Ongoing evaluation of learners' knowledge state, skills, predispositions, and personal context informs optimisation of learning route selection and adaptation of content delivery. Adaptive learning thus tailors the educational pathway according to the learner's evolving requirements within specific subject and topic areas (August and Tsaima, 2021).

Intelligent mentoring and feedback mechanisms constitute the second area of application. Conceptual understanding, knowledge acquisition, skills development, and habit formation represent key learning foci supporting mentality development. AI-driven feedback specifies particular aspects—ranging from timing to content—that govern feedback delivery during the learning process, thus enhancing the promotion of mentality growth.

Automation of assessment, evaluation, and data-informed insights constitutes the third application area. Investigation of learners' knowledge, competence, and mentality requires ongoing measurement of numerous indicators. Dashboards designed for instructors and other stakeholders provide rapid, clear, data-driven insights into key trends and progression, facilitating timely, targeted follow-up actions and decision support that further promote students' mentality formation.

Finally, learning analytics dedicated to mentality development constitute the fourth area of application. Insight into the development of metacognitive awareness, self-regulatory capacity, and social-

emotional intelligence enhances understanding of students' mindset and mentality states. AI tools process data continuously, capture indicators for quantitative analysis, and implement the complete data collection, cleansing, maturation, modelling, and re-utilisation lifecycle.

3.1. Personalization and Adaptive Learning Pathways

Personalized and adaptive learning systems have emerged as the most widely adopted applications of AI in education. By tailoring instructional materials and activities to individual learning needs, they seek to enhance the pace, depth, and breadth of knowledge acquisition and skill mastery (August and Tsaima; 2021). These systems operate using various algorithms—some based on model-driven educational theory and others employing machine learning to analyze and predict learning behavior. They typically draw on input signals such as learner characteristics, activities, performance, and social context. The ultimate goal is to enhance motivation, engagement, and satisfaction while enabling timely adjustments to the learning pathway.

Vitagen-based education, in which educational content represents a learner's embodied knowledge and experience, points toward a specific customization target when developing personalized, adaptive pathways. Existing capacities of the learner—including their knowledge, experience, emotional state, motivation, and personal interests—constitute the individual learner model. AI-supported activities can thus help students define objectives for mentality development and monitor progress toward associated goals.

3.2. Intelligent Mentoring and Feedback Mechanisms

Personalization and adaptability remain core concepts of intelligent tutoring systems. The emergence of procedures allowing adaptation of learning objectives and learning pathways to students' needs and interests marks a significant development (August and Tsaima, 2021). Starting from an initial student profile estimation, intelligent algorithms generate personalised recommendations regarding learning objectives across the curriculum that take into account learner prerequisites (Köbis and Mehner, 2021). In order to modify learning pathways according to particular topics of interest, receivers may signal topics they wish to explore further, enabling an even higher degree of adaptation.

Such personalisation mechanisms harmonise with the structure of the vitagen-based educational scaffolding on two main accounts: the type of encouragement offered and the developmental aspect targeted. Specific flexibility mechanisms correspond to the type of support provided synchronised with the development of evocation. Initial signals offer guidance on an overall set of topics across the holistic curriculum content to consider selected by learners based on diverse prior engagements. Such initial topics constitute objectives pursued when building a solid vitagen-based curriculum, to be systematically circulated across all vitagen-based learning, encompassing a wide progression range prior to reaching more intricate thematic strands, hence strengthening the impetus and engagement projected.

Automation of topic selection further eases the burden on students' reflection processes and encourages them, thereby promoting additional exploration opportunities actively camouflaged within the main objective. The capacity to select different topics not only broadens the cumulated quantity scrutinised but also increases the number of simultaneous curricular aspects probed, leading to heightened exposure and exposure variability, two pivotal characteristics fostering accelerated and enhanced mentality development. Consequently, delivering tailored paths constitutes a salient factor in promoting a wide-ranging mentality focus, amplifying exposure multiplicity and variability, and ultimately stimulating students' mentality growth.

3.3. Assessment, Evaluation, and Data-Informed Insights

AI-driven vitagen-based education relies on various assessment and evaluation strategies and data-informed insights. Assessment for learning is an integral part of the educational process since it provides timely feedback on learners' needs and how much they understand about the vitagen concept and its benefits (Kadel *et al*., 2024). Assessment of learning can be deployed to monitor learners' existing mentality and the extent of mentality development over time (Luan *et al*., 2020). Formative assessment focuses on learners' actions, and data such as recorded video footage, embedded timestamps, sketch compositions, and provided documents are common input signals. These data are indicative of the learner's state of mind

during the educational process, allowing a better understanding of the action taken while learning vitagen-based education. Assessment also identifies collaborative learning involvement and the opportunities for interaction among learners pursuing the same strand under the same educational context.

3.4. Learning Analytics for Mentality Development

Learning analytics constitutes an additional AI-enabled intervention capable of fostering reflection, self-regulation, and socio-emotional development among students. These aspects of mindset fall within the broader construct of mentality, which encompasses intelligence, character traits, and the cognitive and socio-emotional processes supporting lifelong learning (Rienties *et al*., 2024). Mentality increasingly influences student success in formal education, the workplace, and society (Roberts *et al*., 2016). Learning analytics enhances student decision-making and promotes desirable mindset outcomes through increased awareness of learning processes (Yan *et al*., 2024). The interventions operate via a data lifecycle comprising data collection, reporting and visualization, and action planning and intervention. Input signals include interaction, participation, performance, and socio-emotional data from both artefacts and infrastructure.

4. OPPORTUNITIES FOR DEVELOPING STUDENTS' MENTALITY

Emerging opportunities for AI applications in vitagen-based education relate to developing students' mentality. Four core areas for further exploration in this context include enhancing reflective practice and metacognition, fostering agency and motivation, extending socio-emotional learning, and supporting empathetic reasoning.

Students may cultivate reflective practice and metacognition through AI-supported engagement in structured reflection cycles, responding to prompts, providing evidence and justification, and assessing the quality of prior cycles (Mollick and Mollick, 2023). AI can assist by generating prompts to stimulate and scaffold reflection, providing feedback on quality that encourages depth of thinking, evaluating the extent to which evidence is corroborated by activities undertaken, monitoring the frequency of completion, signalling lengthy intervals between cycles, and signalling repetition of similar topics (Xu, 2024).

AI technologies have the potential to stimulate growth mindset, agency, and motivation via goal-setting, provision of autonomy support, and opportunities for progressing from low to high levels of autonomy. Generating suggestions for broad, subject-specific, and granular goals, together with curated autonomy-supportive practices and materials tailored to individual learning goals, constitute a further set of automated opportunities.

4.1. Enhancement of Reflective Practice and Metacognition

AI language models (e.g., ChatGPT) can enhance students' reflective practice and professional metacognition through structured guidance. Reflective practice catalyzes deeper learning and personal growth by encouraging practitioners to critically analyze experiences and develop action plans (Xu, 2024). Professional metacognition–learning to learn–enables trainees to optimize their learning processes, particularly in practice-based contexts characterized by uncertainty, unpredictability, and complexity (Donnelly *et al*., 2025). AI systems can facilitate these processes by scaffolded learners through cyclical reflection with targeted prompts centering on description, analysis, synthesis, and action planning (Kolb, 1984; Kuhlthau, 2004; Liang & Chen, 2019; Osterman, 2005). Frameworks for reflective practice and agency, complemented by AI-enhanced reflection, guide the design of structured prompts for effective deployment.

Reflective practice promotes deeper learning because analyzing experiences, rather than simply recording them sequentially, fosters richer reflection. Students benefit from oral and written accounts of goals, activities, and results that shift attention from pure output to underlying rationale and insights. Effective planning, particularly with learner-generated action, increases accountability and content retention.

4.2. Fostering Agency, Motivation, and Growth Mindset

Motivation greatly influences learners' choices and behaviours in educational settings. It determines the sustained effort, attention, persistence, and energy devoted to available education. Many researchers regard motivation as one of the most important variables predicting students' learning, achievement, and success across a range of academic subjects and educational settings. The stages-channel, growth-mindset, and self-determination theories are among the most prominent and widely studied motivation-related theories. Channels describe the direction and action of motivation and regulate goal-setting. Motivating

students to identify and set attainable learning goals, especially related to learning literature, can increase chances of successfully achieving goals. Improving cognition among junior high-school students is particularly critical; targeted literature-related goal setting has a profound impact on learning progression, engagement, outcomes, and benefits that transfer to other subjects. Students tend to monomotively choose literature-related subjects for a specific period. Such limited motivation for goal-setting severely constrains the effectiveness of later educational steps. The reinforcement of setting literature-related goals can establish a virtuous-cycle motivation, which gradually echoes back to the channels stage. Finally, another major impetus behind students' capability and willingness to learn stimuli and to achieve assigned subject goals lies in stimuli posed by other users, including family, teachers, and fellow students. Supporting students in recognizing and anticipating such external helpers and getting involved in their scheduled or planned goals for ongoing motivation, nourishment, and audio-visual simulation can significantly enhance entire literature education (Reyes-Ortiz; 2019). Both self-determination and growth-mindset theories address the need for individual autonomy for agents to become independent and self-directed. Providing junior high-school students with practices and environments to freely select affecting factors at a personal fine-grain level, especially those with pedagogical footage, can powerfully nurture sustained autonomy. Such unidirectional feeding in turn empowers students to pursue greater motivation exploration with higher autonomy, thus supporting continuous forward momentum. Encouraging student recognition of external role partners at early phases entails engagement in multithreading role-playing smoothly across self, fellow students, family, and teachers. Recognizing ongoing efforts from these other-sided agents strongly influences perception of capability to overcome challenges, thereby continuously stimulating the urge and intention to learn. In light of different roles played by other agent inputs and the necessary base grow towards self-choice and independence, the milestones of exponential self-degreeare progressively dually defined, targeting pedagogical media from other role partners and extended scope into personal active selection from assistive learning environments (Ku and Stager, 2022).

4.3. Socio-Emotional Learning and Empathetic Reasoning

AI-based vitagen education supports socio-emotional learning through collaborative projects that promote opportunities for perspective-taking and empathetic reasoning. For example, students may investigate a global issue through a simulated United Nations assembly, consider diverse viewpoints, and propose solutions aligned with collective interests. AI applications extract and analyze non-verbal data, enabling automatic and non-intrusive monitoring of affective states such as emotions, engagement, and arousal (Tan *et al*., 2022). Automated and non-intrusive feedback can then prompt learners to reflect on the socio-emotional dimension of their interactions, allowing investigation of how feelings and climate evolve throughout the project. Such functionality is designed to support self-regulation by nurturing awareness of socio-emotional aspects and consideration of diverse perspectives.

5. EMERGING RISKS AND ETHICAL CONSIDERATIONS

The integration of artificial intelligence (AI) in educational systems has the potential to foster students' mentality development through vitagen-based education. This paper conducts a systematic examination of the opportunities afforded by AI applications but also identifies emerging risks. Four dimensions of concern are explicated: privacy, surveillance, and data governance; algorithmic bias, fairness, and inclusivity; dependency, autonomy, and critical thinking; and mental health and well-being (Franco D'Souza *et al*., 2024).

Vitagen-based education or vitagen learning is defined as an emergent approach that encompasses anyone seeking to develop and cultivate mentality throughout life, at either a personal or professional level. A participant, termed a vitagen seeker, engages in such learning by managing their own learning goals (Borenstein and Howard, 2021). The term "mentality" refers to characteristics such as self-regulation, metacognition, motivation, personality, and socio-emotional competencies. It is distinguished from "knowledge," which is often the primary focus of education and denotes discipline-specific proficiency. A broad spectrum of educational paradigms and language frames of reference exists, yet without generalisation, it is assumed that broadly-defined mentality development is a cherished and noble educational aspiration in numerous cultural and linguistic contexts. AI technologies can augment vitagen-based education by providing personalised learning pathways, intelligent mentoring and feedback, assessment and evaluation facilitation, and actionable pedagogy and curriculum insights

5.1. Privacy, Surveillance, and Data Governance

AI can bring educational opportunities, but it comes with emerging ethical risks, including privacy, surveillance, and data governance. Furthermore, since vitagen-based education relies heavily on AI, these risks assume a heightened significance.

Education in accordance with the principles of open learning and encouraging self-governance may help mitigate these risks. Emerging AI applications that support vitagen-based education include personalisation and adaptive learning pathways, intelligent mentoring and feedback, assessment and evaluation for decision support, and learning analytics tracking growth in metacognition, self-regulation, and social-emotional skills. Integrating these applications may help to realise the pedagogical and social goals of vitagen-based education.

In the absence of appropriate safeguards, however, these same applications could also reinforce traditional, behaviouristic pedagogies and lead to excessive reliance on external systems. Safeguards such as involving learners in design discussions, using learners' local devices, and making activities on data visible to learners, teachers, and parents could promote agency and autonomy. Yet reinforcing the need for such mechanisms, existing applications of AI in education have sparked ethical concerns about transparency, accountability, bias, and the erosion of agency (Lakkaraju *et al*., 2024).

5.2. Bias, Fairness, and Inclusivity in AI Systems

Concerns about fairness, bias, and inclusivity across social dimensions are paramount. From a vitagen-based perspective, AI should promote growth and liberty, developing learners' agents and decision-making rather than dictating what or how they should think. While a multidimensional view of fairness encompasses non-discrimination and equitable access to beneficial AI, fit-for-purpose assessments, and equitable AI itself, educational settings make bias prevention and proactive mitigation the proper focus. Audit procedures include examine system architectures and functionalities, actively curating training data, proactively conducting impact assessments, and engaging diverse stakeholders in systematic reviews of model performance to identify potential inequities in learner experience and opportunity (Utterberg Modén *et al*., 2025). Representations in training data should reflect the range of social dimensions, identities, and attributes significant in the vitagen context. Fairness metrics should assess not just access but the comprehensiveness of learners' exposure to different social dimensions, aiming for broad and inclusive coverage of learning experiences and orientations over time (Bohdal *et al*., 2023).

5.3. Dependency, Autonomy, and Erosion of Critical Thinking

AI tools, writing assistants, and content generators enable students to complete writing tasks with minimal effort, posing a risk of dependency and erosion of critical thinking skills (Schiff, 2021). Encouraging autonomous planning, outlining, drafting, and self-feedback reduces this risk (Xu, 2024). Supplementary tools that promote original idea generation, provide detailed introductions and outlines, suggest content organization and transitions, and generate self-explanatory critique enable students to retain control and authority over their work. ChatGPT's high-level critique, planning, or brainstorming prompt alongside early drafts serves as a well-balanced approach to maximize utility while safeguarding ownership and independent thought. Integrating and interacting with these AI writing tools via human-centered and non-instrumentalized approaches mitigate dependency and ensure development of valuable knowledge, reasoning, critical thinking, and problem-solving skills.

5.4. Mental Health and Well-Being Implications

AI applications in vitagen-based education create opportunities for supporting students' mental health and well-being and mitigating risks. AI enables the early screening of mental states, the provision of personalized support resources, and the identification of students in crisis and the activation of timely intervention protocols.

Digital technologies can help assess students' well-being by capturing signals associated with educational stress (Hawes and Arya, 2023). Signals may include textual sentiment and rates of expression, types and outing of words, and gaps in percentage of time spent on screen. Based on patterns identified in such indicators, educational institutions can signal resources available for overcoming challenges (Mitsea *et al*., 2023). These resources may be in the form of team gathering to brainstorm ideas, counselling services, or spaces dedicated to specific discipline. Providing readily-available psychological assistance or well-being resources that match students' needs when burdens

reach a critical line is helpful to facilitate their progress on learning tasks without excessive occupational incapability (Xu, 2024). Attention from guardians can be sought when indicators pointing at critical line continuously remain.

6. PEDAGOGICAL AND POLICY IMPLICATIONS

The rapid advancement of AI technologies holds great promise and poses significant challenges for vitagen-based education, which is increasingly gaining traction among educators and learners. Young people have been heavily exposed to the Internet and digital technologies; therefore, the vigour of their learning, thinking, and identity establishment has undergone remarkable but uneven changes since the pandemic. Many students have experienced an unprecedented erosion of agency through excessive screen viewing and prolonged online engagement, prompting widespread contemplation on education to bring about new equilibrium. Mentally, they are confronted with the urgent need to shift from passive digital consumption to a more active and engaged approach (Schiff, 2021).

Curriculum design and instructional practice represent critical bridges connecting pedagogy and policy to practice. To assist educators in implementing AI applications aligned with the learning and mentality development goals of vitagen-based education, clear training provisions and an example framework have been established. Such initiatives are vital, as AI technologies and tools are widely adopted across both developed and developing regions. In particular, the situation pertaining to data protection and privacy differs widely across regions. Supportive educational policies need to carefully strike the balance between the potential opportunities and the associated risks accompanying the usage of AI technologies and tools.

6.1. Curriculum Design and Instructional Practice

A vitagen-based educational approach aims to assist learners to acquire not only cognitive knowledge, but also to form mentality and character attributes, with special emphasis on AI integration for the development of productive mindset, personality, and mental health. AI applications can help students enhance reflective practice and promote self-agency through personalized coaching and mentoring interventions.

An AI educational platform built on learning analytics (LA) technology gathers data from various vitagen applications to generate personalized insights into learning behavior that guide students on ways to improve mindset and mentality. Reports focus on reflection, self-regulation, motivation, socio-emotional development, and related topics. The analysis of systematic reflections generated by a VITAGENT also helps students shape a growth mindset, while collaborative, multidisciplinary citizen-science projects stimulate positive behavioral change and encourage socio-emotional maturity.

6.2. Professional Development for Educators

Integrating AI-enhanced vitagen education in classrooms advances students' holistic and profound mentality development but carries emerging risks. Frameworks such as the Growth Mindset Theory underscore that students' disposition toward learning and development profoundly shapes motivation and achievement across disciplines. Vitagen strategies reinforce the overarching aim of cultivating a growth mindset. Embedding AI in vitagen education, however, creates new opportunities and potential risks. Opportunities stem from AI's capacity to enrich reflection, agency, motivation, and socio-emotional awareness—forming core components of a growth mindset. Simultaneously, the prospect of dependency arises as students increasingly rely on AI-generated prompts and feedback. Safeguarding against such risks demands deliberate design of educational practices, algorithms, and data governance.

In the evolution from teacher-driven curricula to learner-driven vitagen education, professional development for educators takes on a new dimension. The aim shifts from training instructors in curricular content and pedagogy to equipping them with competencies for crafting vitagen-rich learning experiences. Supporting materials facilitate implementation in diverse environments. Building capacity across stakeholders—not only teachers, but also educational leaders, curriculum developers, and policymakers—ensures scalable transformation. To nurture mentality development, an array of AI-supported tools and approaches is available. The proposed framework enables educators to design activities around selected AI applications and instructional strategies. A suite of proposed modules addresses mindset-related topics and skill areas complex to teach without AI support.

Evaluating the effectiveness of professional-development initiatives presents a challenge across educational sectors. Many frameworks to gauge the

success of curriculum enactment or pedagogical shift emphasize teacher acquisition of new competencies. In vitagen-based education, educators initially possess the requisite capacities to promote higher-order thinking through a design cycle focused on educational value and student agency (Tseng and Yadav, 2023). Capacity-building efforts concentrate instead on modelling, motivation, and mentoring to nurture mentality development—topics widely recognized as needing greater attention without formalized pedagogical programmes.

Resources implementing these modules exemplify diverse formats and approaches. Micromodules condense essential guidance into accessible segments, suited for gradual updates. Brief demonstrations illuminate the workings and configurations of selected tools; when coupled with mock exercises, they stimulate thinking on application to specific contexts. Alternative formats serve longer sessions or deeper explorations of particular materials; when posted online, participants can engage selectively based on interests. Pre- and post-exposure surveys gauge shifts in mindsets and awareness of support resources. Documenting engagements through varied media informs individual reflections, broader discussions, and follow-up invitations. Monitoring recipient uptake of proposed materials aids understanding of demand and cross-environment dynamics.

6.3. Governance, Accountability, and Stakeholder Roles

Governance and oversight are crucial components of any educational implementation of artificial intelligence (AI). The unique power and rapid sophistication of AI necessitate heightened attention to the principles and guidelines governing its deployment. In the realm of vitagen-based education, diverse stakeholders hold various responsibilities with respect to governance, accountability, and oversight. At the highest level, national- and institutional-level policies establish broad frameworks that set expectations for the integration of AI in educational applications. Multiple, complementary actors assume roles at the institutional level; governance at this level remains a pressing issue in many contexts. Educational institutions, principals, and educators themselves each bear distinct obligations and functions.

Widespread engagement by these stakeholders is essential for the effective deployment of AI within vitagen-based education to support the development of students' mentality. On the national policy front, collaborative frameworks that encourage ongoing, inclusive dialogue among major parties are crucial for establishing reliable and realistic provisions. Such frameworks benefit all parties involved through guidance and assurance concerning enduring principles, norms, priorities, and actions. Within institutions, similar collaborative governance among administrators, educators, and other actors can fulfil significant demands, set precise expectations, and cultivate supportive environments conducive to responsible AI integration. Participation and input across the stakeholder spectrum also aid the articulation of shared goals and promote alignment on desired learner outcomes. Ultimately, a culture of mutual engagement, proactive solicitation of diverse perspectives, and a commitment to transparency can fulfil the demands of vitagen-based education while assuring that students accrue the necessary knowledge to use AI and other tools in a manner consistent with their evolving mentality (Mollick and Mollick, 2023; Choung *et al*., 2023; Xu, 2024).

7. CASE STUDIES AND EMPIRICAL EVIDENCE

To investigate these implications, two types of empirical studies are considered. The first, encompassing the international experience of providing students with opportunities to develop the mentality of a growth mindset and an entrepreneurial attitude, focuses on describing the practices adopted in different educational settings and the outcomes obtained (Rienties *et al*., 2024). Several international educational systems, such as those in Singapore, Russia and selected countries in Africa, have integrated the development of this mentality in their curricula and have adopted pedagogical practices that engage learners both in the scenario of formal education and outside of school.

The second type of empirical studies seeks to analyse the actual impact of training activities targeting either growth mindset mentality or entrepreneurial attitude. The studies undertaken in different countries at both School and University levels present longitudinal observations of students' shifts in mentality as a result of their participation in such training programmes (Mollick and Mollick, 2023). In such studies, the framework elaborated in either Section 1 for the mindset mentality or in Section 2 for the entrepreneurship attitude is retained and the context of the selected educational setting is fully characterised

(appropriate language, type of institution, subjects, length of programme, pedagogical approaches adopted, etc.), with the aim of extracting insights that can be reused in the case of vitagen-based educational systems.

7.1. International Perspectives and Comparative Analyses

The fast-evolving integration of artificial intelligence (AI) into education is the subject of considerable and broad-ranging attention by educational researchers, policy-makers and practitioners (Schiffm, 2021). The emerging field of Artificial Intelligence in Education (AIEd) encompasses AIs that discover, analyze and make recommendations about the interactions between students and their learning environment, widely viewed as a hallmark of contemporary education systems. The term encompasses not only educational software and content but also situations and interactions mediated by laptops, tablets, smartphones or other communication technology. Notable features include the increasing onus on learners to evaluate and act on the information and assistance discovered through educational media. AIEd has the potential to facilitate education, aid transfer and promote learning, to allow for greater openness about content selection and related matters for teachers and students.

7.2. Longitudinal Studies on Mindset and Mentality Outcomes

A longitudinal study explored how mindset and related mentality may differ across the K–12 continuum in a Philippine basic education setting. Conducted between 2021 and 2022, the research compared growth and fixed mindset conditions before, during, and after a blended approach to teaching mathematical content. Key findings indicated shifts in mentality across the four year levels, with a moderate growth mindset preceding the intervention. Only grade ten exhibited a positive trajectory that persisted into the following year, while attitude toward mathematics declined sharply post-intervention across all grades.

Another longitudinal study investigated how growth safety mindset influences students' school-to-work transition intentions and multicultural appreciation in Kazakhstan. Conducted from 2020 to 2023 in a blended learning environment, the research compared the Impact of Information Students' Science−Technology−Mathematics Education on System−Technological Literacy Facilitation–Diffusion and Growth Safety Mindset on Multicultural Appreciation and School-To-Work Transition Intentions. It revealed that the impact of such pedagogy on both transition intentions and multicultural appreciation galvanizes through safety mindset; the greater the influence on safety mindset, the loftier the appreciation becomes, subsequently constraining the transition intentions.

8. METHODOLOGICAL CONSIDERATIONS FOR RESEARCH IN AI-ENHANCED VITAGEN EDUCATION

Research opportunities in AI-enhanced vitagen education encompass curricular design, pedagogical practices, professional development, administration, policy, and governance, yet few rigorous studies exist. Educational paradigms posit that learning does not occur in a vacuum but that experiences must be embedded within a pedagogy framework. In support of the need for systematic investigation, established research traditions are synthesized, with recommendations for concrete designs and strategies to address relatively unexplored yet pressing themes. Experimental, quasi-experimental, or mixed-method strategies—thegold standards—are advocated. Triangulation of quantitative learning analytics with qualitative metrics from open-ended surveys, interviews, video recordings, and learning materials is encouraged.

Ethics remains paramount when human learners are involved. Safeguards must ensure the protection of privacy and the comprehensive management of sensitive variables, such as mentality. A cross-disciplinary, team-based model is advocated, incorporating, in addition to educational experts, regulatory leaders from law, sociology, and philosophy. Clearly demarcated timelines and the incorporation of knowledge-translation activities assist in ensuring that insights arising from engagement feed back, at appropriate levels of granularity, into systematic practice. (Rienties *et al*., 2024).

8.1. Research Designs, Metrics, and Validity

Education programs should equip learners with lifelong skills that help them navigate an increasingly AI-augmented and digital society. Yet programs miss opportunities to cultivate a sense of purpose and help students understand how their learning connects to the real world. Integrating pillars of Science, Technology, Engineering, Arts, and Mathematics (STEAM) with project-based, hands-on learning can enhance knowledge retention by motivating students to explore solutions to authentic problems. Learners benefit from mentorship, but access to informal guidance is uneven.

In an era of rapid change, the responsibility of education is to prepare individuals to adapt to the evolution of society. Yet educational programs typically focus on teaching knowledge and directing skill acquisition. A transformative approach emphasizes the need for education to help students develop a growth mindset and a clear sense of purpose, or a "why." Purpose describes the long-term reason for engaging in day-to-day activities. Engaging courses send students the message that learning can shift mindsets, confirm a sense of purpose, and cultivate curiosity about evolving applications of knowledge.

Applications of Artificial Intelligence (AI) hold great potential for enhancing learning opportunities, but unless society steers the technologies toward productive purposes, they may perpetuate the cycle of acquiring skill without understanding its connection to real-world problems (Van Brummelen *et al*., 2021).

8.2. Ethical Research Practices with Learners

Researchers seeking to advance vitagen-based education through artificial intelligence must adhere to ethical practices that protect learners. Safeguards should address transparency, anonymity, privacy, and risk mitigation, ensuring measures are in place to minimize psychological and physical risks and protect sensitive data from unauthorized access (Latham and Goltz, 2019). Thoughtful consideration of ethical principles in data governance and algorithm design can help prevent bias and group unfairness (Nguyen *et al*., 2023). Specific measures may include:

- Obtaining informed consent. Participants should be provided with clear information to help them understand the nature and purpose of the research. Consent procedures should be sensitive to equity considerations and reflect the local regulatory environment, which may preclude underage participation in certain cases. Providing separate consent agreements tailored to the respective age groups of students and educators may help address this concern.

- Ensuring anonymity and confidentiality. Anonymized aggregate data should be used whenever possible. When specific community contexts and individual scenarios need to be identified, anonymization and aggregation procedures should still be employed to protect participants' identities. Ethical research practices require detailed plans for data retention and destruction aligned with the duration of the research project. The tools and services used to collate, capture, and process such data should also comply with institutional and organizational policies.

- Mitigating psychosocial risks. Researchers should remain vigilant to any indication that an AI system or the data collected is adversely affecting students' motivation, well-being, or growth mindset, and should share findings with the community. Provisions for resources and support should be clearly communicated to both educators and students before sharing data or deploying tools. Criteria for evaluating students' essays, journals, objectives, and artifacts should be established in advance to inform feedback and reduce potential bias.

8.3. Cross-Disciplinary Collaboration and Implementation Research

To investigate the efficacy of AI in vitagen-based education, cross-disciplinary collaboration and implementation research are essential (Mollick and Mollick, 2023). Teams comprising AI developers, educational technologists, cognitive scientists, curriculum specialists, and subject-matter experts contribute to developing innovative applications. Implementation studies in diverse settings within evolving educational systems generate case studies, frameworks, and principles that enhance knowledge translation, refine pedagogical practices, and ensure alignment with learners' abilities, preferences, and socio-cultural contexts.

Collaborative efforts to introduce AI-driven processes, procedures, or activities into vitagen-based education provide rich opportunities for experimentation and investigation. A gradual, delicate approach enables comprehensive exploration of pedagogical strategies while adhering to professional standards of practice, scholarship, learning design, and education.

9. CONCLUSION

Expressions such as "only time will tell" or "the future is uncertain" become clichés precisely because they are true; the trajectory of AI applications remains uncertain. Any initial conclusion, however cautious, will likely be premature. But for society to chart its course wisely amid this uncertainty, it is vital to explore the opportunities and risks that AI applications may present. Past experience with educational

technology—radio, television, video, computers—shows that different areas will not develop at the same pace. To attenuate the emphasis on speculation, it is prudent to present concrete anticipations of AI applications, where at least one opportunity and risk will be delineated for each.

An AI-plausible development is that currently viable AI applications may enhance rather than detract from vitagen-based education. A stimulating conjecture is whether these applications could display the same potential for positive impact that computer- and internet-based applications have shown. A stronger thesis asserts that currently feasible AI applications possess the capacity to elevate vitagen-based education to an unprecedented level. More than mere expedience or efficiency, AI holds the prospect of a transformative leap from traditional to intelligent vitagen-based education, vastly amplifying the range of mood, content, and medium that could enhance leaner mentality. Fuller exploration of the multifaceted nature of AI—as technology, collection of diverse but unified phenomena, and enabler of new capabilities—may yet yield new avenues for conceptualizing opportunities and risks.

Despite the organization of these emerging opportunities and risks, the discussion of curriculum design, instructional practice, and pedagogy has yet to fully elaborate features of AI or outline what actual AI-driven lessons might entail. Long-established, respected notions of pedagogy may still lack sufficient grounding in a vitagen framework, leaving the tentative theme of pedagogy malleable. A smorgasbord of complementary educational strategies buttressed by AI yet unaddressed in the corpus might inform additional design principles for AI-enabled vitagen education. Educators remain acutely aware of the principles that enhance learning; while general pedagogical theories constitute a relatively stable foundation, the plan does not preclude augmentation by further explorations of education-enhancing principles that AI tools elsewhere illustrate approach (Mollick and Mollick, 2023; Xu, 2024)).

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