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INTEGRATING SYSTEMS THINKING AND PROJECT BASED LEARNING IN SUPPORTING BASIC PSYCHOLOGICAL NEEDS: A PROPOSED MODEL FOR FILIPINO STEM STUDENTS

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Abstract: Using a qualitative exploratory methodology, within a constructivism paradigm, this study investigated the effect of a Science Technology Engineering and Mathematics (STEM) project-based Learning (PjBL) with integrated elements of systems thinking model, through the affective lens of Self-Determination Theory (SDT), on participants' self-determined behaviors at a junior high school in Antipolo City, Philippines. The research applied the theoretical perspectives of SDT and qualitatively examined its effect on students' autonomy, competence, and relatedness. Subject narratives revealed patterns of their motivation progression on an established motivation continuum, and how the program, as designed, supported their acquisition of the various elements of self-determination after being exposed to the program. The research found out that the characteristics and nature of the model, in contrast to traditional interventions, reinforced students' self-determination and motivation, not just in their academic outlook, but also their lived realities outside the school. Limitations, contemporary classroom implications, results, and the design of future studies are similarly discussed.

Keywords: Systems Thinking, Project Based Learning, Self – Determination Theory, Philippines, STEM

Motivation, needs satisfaction, well-being and thriving in learning environments have become major considerations in contemporary educational practices because they are believed to have a long-term impact on human development (Ryan & Deci, 2017). Historically, educational theories have primarily focused on the cognitive aspects of education in human development and neglected to foreground the impact of the non-cognitive, affective, and psychological components on learning (Deci et al., 1991; National Research Council, 2011; Ryan & Deci, 2017; Sawyer, 2014). According to the United Nations Development Programme (UNDP), education and learning have been vital elements of human development and societal advancement. Education, on the whole, contributes to the advancement of societies and its impact can be ascribed to future societal advancements (UNDP, 2020). Instructionism, the ubiquitous traditional teaching method, has been a chief practice since educational recorded histories and has been notably driven by the dissemination of factual information, where teachers

are the main source of this information, fixed expectations, in terms of measurable or numeric performance outcomes, employed within environments where power is consigned to the teacher, and where students passively follow with few opportunities to identify their own learning needs or reflect collectively on their experiences (Azer, 2005, Belias et al., 2015; Sawyer, 2014; Wang et al., 2011).

However, as theoretical and conceptual knowledge and practices in education are increasingly informed by social and cultural research, including alternate measures or indicators of success (CAST, 2018; Ryan & Deci, 2017), the primary focus on test scores and teacher centeredness in formal and informal learning environments have evolved (Sawyer, 2014). A major understanding from these theoretical and conceptual underpinnings is, how children learn, is as equal in importance to what they learn (Darmawan, 2020) and forms the basis, in our view, for the need of a major shift in pedagogical approaches. These shifts must include attempts to adapt more autonomy-supportive teaching styles in order to support learners' inherent basic psychological needs by facilitating students' such as students taking on active roles in their learning processes and outcomes (Miller & Krajcik, 2019; Reeve et al., 2022). Additionally, autonomy-supportive teachers consider and involve their students' individual interests and creativity in formal and informal learning spaces by supporting increased access to various non-traditional learning opportunities and facilitating self-directed behaviors (Barron, 2006; Miller & Krajcik, 2019; Reeve et al., 2022; Resnick, 1987; Ryan & Deci, 2017).

These non-traditional approaches that facilitate these self-directed behaviors contribute to the effective transfer of knowledge, attainment of 21st century skills, individual success in their academic, personal and social lives, as well as their well-being (National Research Council, 2011, Ryan & Deci, 2017; Sawyer, 2014). Teacher responsibility in fostering and supporting self-directed behaviors include stimulating curiosity, leveraging peer collaboration in teaching and learning, monitoring group work, promoting teamwork, utilizing strategies that generate deep understanding of content, and creating a learning environment that is engaging and meets the unique needs of each learner, for example, ensuring that pedagogies utilized are culturally responsive (Azer, 2005; Paris & Alim, 2014, Reeve et al., 2022). Collectively, these discrete teacher and learner behaviors are approximations towards self-determination (Ryan & Deci, 2017) and have gained the attention of educators interested in teaching the "whole child" in a variety of learning environments (Slade & Griffiths, 2013).

Given the documented effectiveness of more student-centered approaches in various learning environments (Azer, 2005; Miller & Krajcik, 2019), this study investigated how and what characteristics and features of a bespoke Science Technology Engineering and Mathematics (STEM) project-based learning (PjBL) program with integrated elements of systems thinking, nurtured students' satisfaction of their basic psychological needs (BPNs) or self-determination (Ryan & Deci, 2002; Ryan & Deci, 2017) as a result of participating in our after-school program at a junior high school in the Republic of the Philippines. The researchers specifically

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investigated whether the implementation of the model designed supported the student participants' satisfaction of their basic psychological need for—autonomy, competence, and relatedness— (Ryan & Deci, 2017). By employing a qualitative exploratory approach, within a constructivist paradigm, the researchers examined students' levels of motivation and indicators of BPNs satisfaction based on their written and recorded reflections. The researchers propose that our model not only develops STEM knowledge and competencies, systems thinking, and critical thinking, but is also a promising strategy for supporting students' self-determination across various educational contexts and as a basis of supporting the acquisition of 21st century skills (National Research Council, 2011).

Systems Thinking

Systems thinking is a way of thinking about phenomena and events as a system (Lavi et al., 2021). It is not analogous to thinking systematically, is distinct from other types of thinking, namely creative, critical, and analytical thinking, and is becoming a critical skill for the 21st century (Lavi et al., 2021; Miller & Krajcik, 2019; NRC, 2011). It is a disciplined approach for examining problems more completely and accurately before acting (Goodman, 1997) as it inherently requires asking deeper questions before arriving at a solution. In addition, systems thinking involves using a specific set of tools and language to visually capture and communicate ideas, that is, making thinking explicit (Kim, 1999). As a set of tools, and a language, a systems thinking approach is used to identify patterns, carefully examine data, and look beyond surface occurrences by pinpointing causative factors (Kim, 1999). This approach ultimately promotes sustainable problem-solving through an idealized design process (Ackoff, 1999). This means envisioning an ideal future state, understanding and approaching problems wholistically by recognizing interdependencies and interconnections. Systems thinking requires inquiry, clarity, compassion, choice, courage, the willingness to see phenomena as a whole (Goodman, 1997), and acknowledgement that they are varying solutions to any problem, many of which will not be popular with all stakeholders (Ackoff & Greenberg, 2008; Goodman, 1997).

Self-Determination Theory

"Human potentials can be diminished by impoverished or oppressive social conditions" (Ryan & Deci, 2017, p. 4). So, what do humans need from their social environments to fully function and thrive psychologically? SDT can answer this question as it is fundamentally a view of human behavior, motivation, and personality development that focuses on the social factors that facilitate or impede human flourishing (Ryan & Deci, 2017). Empirical and organismic methodologies primarily inform the SDT lens through which the inherent human capacities for psychological growth, including engagement and wellness, in general and specific contexts, and domains, are enhanced or undermined by biological, social, and cultural conditions (Ryan & Deci, 2017). Significantly, SDT examines how the aforementioned social-contextual conditions

support or thwart humans' basic psychological need for competence, relatedness, and autonomy and what factors optimize functional integrity (Ryan & Deci, 2017).

Ryan and Deci (2017) described social environments in three distinct ways to determine whether or not they optimized functional integrity: (1) autonomy supportive (versus demanding and controlling); (2) effectance supporting (versus overly challenging, inconsistent, or otherwise discouraging); and (3) relationally supportive (versus impersonal or rejecting). Key to autonomy support are choice and encouragement of self-regulation, competence supports contingent on provisions of structure and positive informational feedback, and relatedness supports depend on the caring involvement of others leading to satisfaction of basic psychological needs (Ryan & Deci, 2017).

SDT in Education

Interrelation of The PjBL and Systems Thinking That Leads to SDT Development

Given these core definitions for PjBL, systems thinking, and SDT, the researchers sought to understand how the interrelation of the characteristics and features of PjBL and systems thinking fosters the development of self-determination in learners. The researchers identified commonalities among the three concepts by analyzing the nature of each and derived linkages, interdependencies, and interconnections. The researchers surmised that PjBL learning environments are not overly controlling or demanding, motivating, supportive, and student-centered (Miller & Krajcik, 2019) as students engage in meaningful problem-solving that requires them to make their thinking explicit and culminates in the collaborative production of an artifact (Papert, 1991). Systems thinking is primarily a problem-solving and wholistic thinking framework with a unique language and inherent tools that facilitate visualization for making thoughts explicit (Kim, 1999). Last, SDT relies on motivational factors, both intrinsic and extrinsic, including scaffolding to meet humans' basic psychological need for autonomy, competence, and relatedness in structured environments. This claim is supported by the following quote:

Structure, as a scaffolding and support for competence, is shown in many SDT studies to complement autonomy support. In fact, classroom climates supporting autonomy, providing high structure, and conveying relatedness and inclusion foster personal well-being and feelings of connection to one's school and community. (Ryan & Deci, 2017, p. 18)

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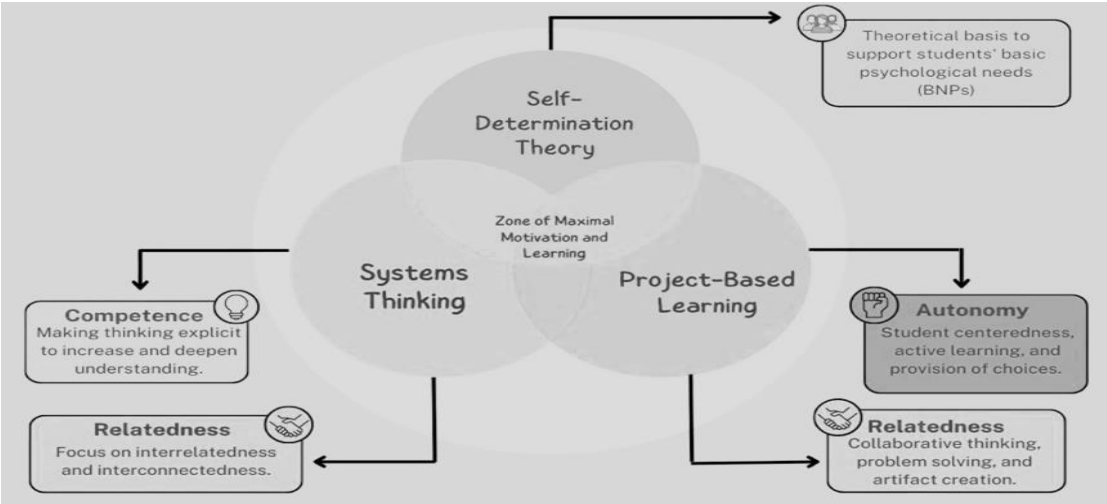
Figure 1

Researchers' paradigm in designing the STEM project-based learning with integrated elements of systems thinking model for SDT Outcomes



Visualization of the three theories applied to our designed model (Self-determination, Constructivism, and Systems Theory) and the constituent elements that converge to form the basis of an optimized learning environment (Kim, 2017; Ryan & Deci, 2017) that maximizes opportunities for the development of intrinsic motivation in learners.

Common characteristics that link the three concepts together are choice, scaffolding, and motivation, which are also key components of self-regulated learning (Stefanou et al., 2013). Self-regulated learning refers to student control of the learning process, which is demonstrated by, but not limited to, learners as active participants in learning who construct meaning from information available in the environment in combination with what they already know and learners who control and regulate aspects of their thinking, motivation, and behavior and in some instances, their environment (Stefanou et al., 2013). According to Stefanou et al. (2013), PjBL contexts appear to provide the optimal environment for students to exercise autonomy and cognitive behaviors associated with self-regulated learning.

STEM-PjBL with Integrated Elements of Systems Thinking Model

In order to design a model that integrated the elements of systems thinking in a STEM-PjBL after-school program, the researchers identified specific systems thinking elements and matched and incorporated them in each phase of PjBL. The researchers intentionally selected specific elements of systems thinking (complexity, interconnectedness, interdependencies, feedback, and cause and effect) by examining the nature of PjBL experiences as described in research literature and matched the concepts, ideas, and skills that were congruent.

Chandrasekaran et al. (2015) described the process of PjBL as a student-centered activity

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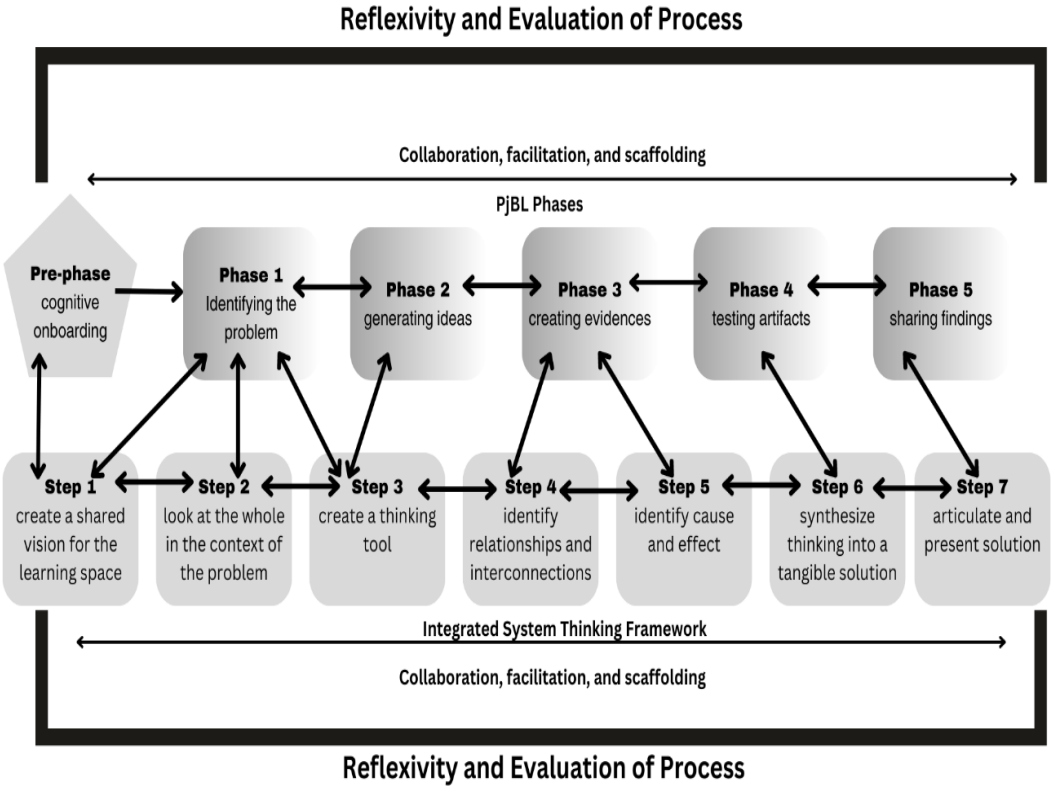
which is comprised of five different phases. These phases include: (1) identifying the problem (2) generating ideas, (3) creating evidence(s), (4) testing artifacts, and (5) sharing of findings. For the purpose of this study, the researchers adopted these phases in the model design creation. Additionally, the researchers included a pre-phase labeled *cognitive onboarding* which the researchers added to establish norms, expectations, and guidelines, and to provide the learners with the tangible and cognitive tools to be used during the program.

Subsequently, the researchers identified the elements of systems thinking that the researchers believed naturally existed in the PjBL process. After identifying and analyzing these elements, The researchers then labeled them as the Seven Systems Thinking Steps which are: (1) creating a shared vision (Senge, 2006), (2) looking at the whole (Ackoff, 1999), (3) creating a thinking tool/model (Kim, 1999), (4) identifying relationship and interconnections (Ackoff & Greenberg, 2008), (5) identifying cause and effect (Kim, 1999), (6) synthesis (Kim, 1999), and (7) articulating solutions (Ackoff & Greenberg, 2008).



In order to merge and integrate these two concepts, STEM-PjBL and systems thinking, in a model, the researchers utilized established PjBL and systems thinking strategies and activities such as questioning, simulations, brainstorming, model creation, among others (Ackoff & Greenberg, 2008; Kim, 1999; Miller & Krajcik, 2019). The detailed implementation framework, associated with the integrated design model, that the facilitators and the students performed

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throughout the program, can be provided upon request from the authors. Figure 2 presents the conceptual framework of the design which shows the intended delivery and the iterative process associated with the model. The visual of the model presents the alignment between these two concepts highlighting the critical, reiterative, collaborative, reflective, and reflexive processes the researchers believed provided a learning environment that will promote self-determination among the participants.

Research Question

This study explored the nature and characteristics of the designed program that promoted student's self-determination. Specifically, the researchers sought to answer the following research questions**:**

1) What evidence of SDT is revealed from the narratives of the respondents?
2) How do these experiences inform our understanding of the relationship between these two approaches of learning and student's self-determination?

Research Methodology

This study applied the rigor of the qualitative methodology to identify the characteristics of the designed program that lead to the support of self-determination in the student participants. Various authorities have concretized the definition of qualitative research while emphasizing its processes that foreground social phenomenon, human lived experiences, and life narratives in natural contexts through analysis of their subjective experiences, perspectives, and the meanings they ascribe to these lived experiences (Creswell & Poth, 2018). Yin (2011) discussed qualitative research design goals as a means to explore and understand complex phenomena that cannot be defined numerically due specifically to its interpretive and constructivist nature. Exploratory methodology is a form of qualitative research design, based on the constructivism paradigm, where the researcher seeks understanding from the perspective of the research participants specific to the phenomenon, program, or experience under study (Charmaz 2006; 2014) in a manner that is open-ended and flexible (Creswell & Poth, 2018; Merriam & Tisdell, 2015) rather than testing previous hypotheses or theories. According to Charmaz (2014) the exploratory methodology aims to generate a theoretical framework (insights and perspectives) formed from codes and subsequent categories and themes derived from data analysis. This type of iterative, emergent characteristic of qualitative research is beneficial in understanding the respondents' experiences towards the program from the examination of detailed data collected such as interviews, observations, and document analysis (Creswell & Poth, 2018; Merriam & Tisdell, 2015).

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Results and Discussions

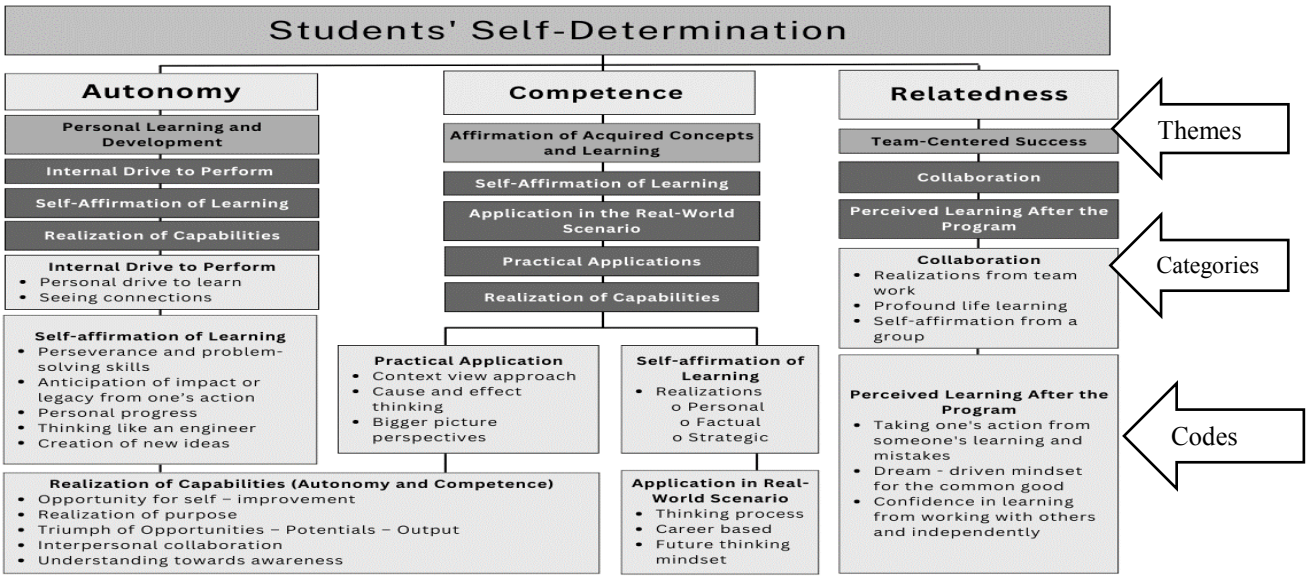
Research Question One: What Evidence of SDT Is Revealed from the Narratives of the Respondents?

Qualitative Analysis: Themes, Categories, and Codes

The narratives analyzed consisted of individual student participants' reflection journal responses which were based on prompts provided by facilitators, their independent reflection video recordings, and entries from their group journals. The narratives also included the participant teachers' survey responses, recorded daily debriefs, and research observations and memos. The results of the thematic analysis are summarized in Figure 3. The three main themes are discussed forthwith.

Figure 2

Summary of the Thematic Analysis of the Students' Narratives, Journal Entries and Interview Responses



Note.

Theme One - Autonomy in Learning and Personal Development. The first theme revealed is autonomy in learning and personal development (Ryan & Deci, 2017). This theme relates to learner volition and their perceptions about making choices based on their own thoughts, decisions, and actions (Ryan & Deci, 2017). In this context, this means the freedom, or the degree of willingness, the participants experienced in moving towards the direction of their

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goals (learning, personal, professional, social) while recognizing possible constraints and challenges (Ryan & Deci, 2000a). The participants' narratives shed light on how they exerted their autonomy, remained engaged, and embraced their learning challenges to solve an immediate problem to attain current and personal development (future) goals (Ryan & Deci, 2000b). Relevant to the theoretical constructs of SDT, specifically the autonomy-control continuum, proactive engagement, self-regulation, and internalization (Ryan & Deci, 2017), this theme aligns to the identification of motivation and engagement and its influence on the participants' perceptions and behavioral outcomes (Ryan & Deci, 2000b).

This is further supported by the statements:

"I can connect what I learn from this program to my life by thinking that I should do better, and I should keep learning," and, "I learned from this program is hindi na nababawasan yung expectation ko sa mga subject ko na learn ko na gawin ko yung best ko hindi lang para sa grade na ineexpect ng tatay ko *(my expectations to the subjects are not lessened while trying to do my best and not only for the grades that my father expects me to have)*. Not only for the people that expects something from or wants me to be in the future."

The following two quotes further exemplify how persevering and problem-solving in anticipation of impact or legacy coming from personal action may contribute to internalization:

"The most important thing I learned today is don't give up, come up with a solution and solve the problem."

"My reflection for today "is progress" and today and I've made some big adjustments and progress, of course. Those progress is a leap to a better me…"

These narratives are indicators of the participants' ability to demonstrate autonomy and remain engaged during even difficult moments in their learning and how it relates to their personal growth and development. Autonomy is a critical element of SDT as it suggests intentionality (Stefanou et al., 2013) and the development of unforced decision-making (Boggiano et al., 1993) which are indicators of an internal perceived locus of causality or autonomy engagement (Ryan & Deci, 2017). Overall, the theme of autonomy in learning and personal development highlights the importance of providing a learning environment that is autonomy supporting and promotes self-regulation (Boggiano et al., 1993; Ryan & Deci, 2002) without compromising on rigor and structure (Ryan & Deci, 2017; Reeve, 2022). In such environments, learners have the latitude to confront challenges and reconcile them in their own way which limits the development of introjected behaviors (Ryan & Deci, 2017).

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Theme Two - Affirmation of Acquired Concepts and Learning. Theme two—affirmation of acquired concepts and learning—can be explained by participants' realization of their knowledge and skill acquisition and awareness of their growth in content area and factual knowledge, personal and interpersonal abilities, organizational competencies, and strategic skills (Deci et al., 1991). These may be indicators of feelings of effectiveness and mastery (Ryan & Deci, 2017). Within the implementation environment, affirmation of acquired concepts and learning is distinguished by utterances, expressions, and behaviors demonstrating understanding of new concepts, making connections to immediate and future consequences, sharing previous and new knowledge, and sharing application suggestions (Deci & Ryan, 2009). For instance, statements such as:

"Systems thinking helped me to think strategically. I use and flex it to my classmates. I taught them how to use it and to think about cause and effect."

"What I learned today, I can apply it for the next weeks to commit to my everyday by using my eyes to observe within surroundings and observe what problems may occur."

These quotes are indicators of their realizations of opportunities for self-improvement and purpose. Participants' narratives also provided insight on their perspective on their cognitive and interpersonal growth stemming from their experiences during the program:

"Another thing I learned in two weeks is systems thinking, considering cause and effect and making a thinking model. You're able to articulate solutions after looking for the possible problems or the cause of it. You'll be able to appreciate every function when you know the use of everything."

These narratives regarding realizations of knowledge and skills acquired, reveal the participants' understanding and appreciation of their increasing competence and the ability to adapt to new challenges in novel contexts (Deci & Ryan, 2000). Furthermore, perceived competence is linked to increased engagement, intrinsically motivated activity, deeper learning (cognitive growth), motor, and social growth (Boggiano et al., 1993; Deci & Ryan, 2000). The theme of affirmation of acquired concepts and learning underscores the importance of learners' feelings of effectance and mastery (Ryan & Deci, 2017) in learning environments and its impact on learner motivation, internalization, expertise and identity development, sense of belonging, interest development (Barron, 2006; Ryan & Deci, 2017), and how vulnerable or at risk they are of being thwarted (Ryan & Deci, 2017).

Theme Three - Team Centered Success. The third theme that emerged was team centered success (Ryan & Deci, 2000a). This theme relates to learner satisfaction gained from working with and playing a significant role in achieving success with others as a part of a team (Ryan & Deci, 2017). In this context, this means, participants' insights and affirmations resulting

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from collaborating with others to meet agreed upon objectives, self-affirmation gained from the group, demonstration of creativity in solving problems, engaging in behavior consistent with established socialization norms within the learning context, and general enjoyment and feelings of belongingness while working with others. The participants' declarations confirmed that they benefited not only technically, but socially and emotionally, while engaged in teamwork leading to profound statements about their experiences:

"I will use the things I learned [from others] from the program in my own life."

"I always believe that no man is an island and my experiences in the program prove it"

"My experience taught me how to socialize more and taught me how to socialize with new people. So much thing that you can learn from each other. Celebrating what they have 0064one."

SDT posits the idea of differing degrees of drive, motivation and regulation across a continuum ranging from 'non-self-determined' to 'self-determined' (Ryan & Deci, 2017). This concept, encapsulated in the Continuum of Relative Autonomy (Ryan & Deci, 2017) as a subset of the Organismic Integration Theory, formed the basis of including in our investigation if the student participants underwent changes, in terms of their motivation, while participating in the intervention, as indicators of the methods and strategies employed in the learning environment were needs-supportive or needs-thwarting. A week after the program, the researchers returned to the school and invited the students for a focus group discussion where the participants were asked to reflect and describe their overall insight about their experiences. Guided by a semi-structured interview protocol, the researchers elicited then analyzed the students' motivations for joining the after-school program to determine and explore whether the participants exhibited basic psychological needs satisfaction in a progressively linear manner across the continuum as revealed through their narratives about their experiences. Figure 4 visually summarizes the derived from their responses and is explained in detail below.

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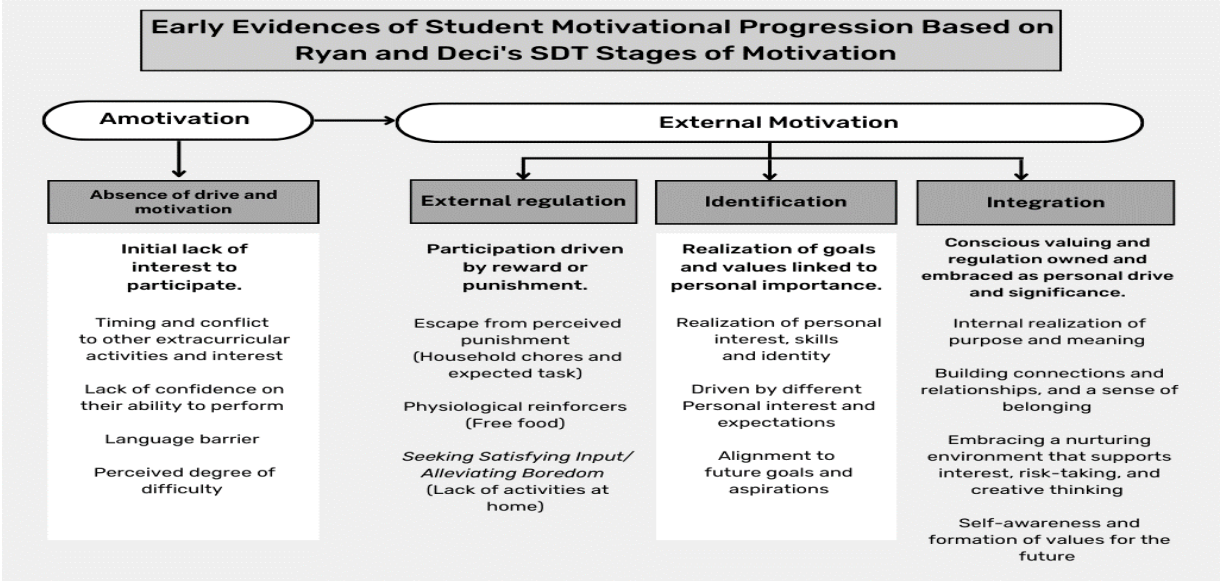
Figure 3 *Early evidence of students' motivation in the STEM-PjBL with integrated elements of systems thinking program*



Student motivation progression throughout the span of the intervention ranging from amotivation to integrated regulation.

Amotivation: Lack of Interest to Participate in the After-School Program

The first theme identified was an initial lack of interest in participating. Such a theme can be attributed to "amotivation" which Ryan and Deci (2017) defines as the lack of interest and engagement in performing an activity. Cheon et al. (2016) states that this lack of intention to act can be due to the perception that there is little or no reason for their effort. In the interview, students stated that they initially did not have the interest in joining the program because of several reasons such as, less time to engage in desirable personal activity, insecurity about cognitive capability and perceived program difficulty, perception that the intervention would not offer new challenges, and perceptions that the intervention required mastery of the English language. Narratives specifically related to their initial perception include:

"During this time (referring to the time of the program), I am already sleeping soundly at home. I'll use cell phone, watch T.V. At first, it's hard to adjust because I woke up at 5am. As early as 5am I am already awake. Then if I join, what time will I be going home?"
"Actually, I don't want to join. I ask myself, in our section, why am I chosen? There are other smarter kids than me. I was amazed because I was selected."

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"I really didn't want to join initially but my teacher told me to. That's because I am a part of the volleyball team. We have games."
"I really don't want to join because they speak in English."

The timing of the program, language barrier, perceived difficulty of activities, conflict with other interests and extracurricular activities together with their lack of self-confidence in STEM led the students to initially demonstrate hesitations and a lack of interest towards the program. Their narratives suggest that students considered various factors which affected their motivation, engagement, and willingness to participate.

Extrinsic Motivation

The second and third theme derived from the participants, are linked to behaviors further along the continuum of relative autonomy associated with external regulation and identification, includes participation driven by punishment and reward and realizations of goals and values linked to personal importance. People may act volitionally outside of intrinsic motivation when motivated extrinsically or through identified regulation (Ryan & Deci, 2000a; Ryan & Deci, 2000b; Ryan & Deci, 2017). Extrinsically motivated means to act to obtain external rewards or to avoid punishment (Ryan & Deci, 2017) rather than the energizing inherent interest and enjoyment linked to intrinsic motivation (Reeve et al., 2022). Additionally, motivation may be initially externally regulated but may evolve to identified regulation as individuals begin to personally value the activity as meaningful and beneficial (Ryan & Deci, 2017). Narratives from some students revealed that they initially agreed to participate due to external motivational factors specifically, to avoid imposed activities at home, perceived punishment of those activities, or to obtain external rewards (Ryan & Deci, 2017; Vansteenkiste & Ryan, 2013). When asked why they decided to pursue the program, some students mentioned:

"I told myself, if I join the program, I will be at home past 3pm. Well, during that time, all the dishes are already washed. Plus, I have free food!"

"Yeah, like what they said, so I dodge my mom's orders. Then, there's free lunch. If I go home, it's boring, I don't have anything to do. Sometimes, I just raise my hand to join activities that I can do because at our house, when I get home, I'm starving, there's no food."

In this case, the students were influenced to participate because of their awareness that lunch would be provided. The satisfaction of a physiological need served as an incentive that motivated the students to participate. Moreover, students also made comments such as:

"So that I won't do chores my mom ask me to do. It's quite a lot!"

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"When I get home, I have to go to the market, wash the balut (duck eggs), then I will have to boil them. So, I took advantage of the program in addition to the fact that I will be given free lunch. Every time I go home, the balut is already cooked and all I have to do is to sell it. Hahaha on my goodness!"

Conversely, the presence of aversive factors revealed that other students were also motivated not because of a reward (food), but because they wanted to avoid what they perceived as a punishment at home. Many of the students are expected to help with household chores after school and they perceived this as a burden and to some, even as a punishment. Joining the after-school program was a way of avoiding the imposed tasks and this motive initially led them to join the program.

Some students also expressed reasons for participation related to regulation through identification (Ryan & Deci, 2017). This type of motivation is described as autonomously acknowledging and embracing the value of an activity the individual does not necessarily find inherently interesting or enjoyable (Ryan & Deci, 2017; Vansteenkiste & Ryan, 2013). Narratives such as the following exemplified this argument:

"My teacher said, just to try and enjoy the program. Maybe at the end you don't want to stop anymore. Which really happens. Slowly, I am just curious why we will make a bridge? Why bridge, if we can make another easier project. Then, in the process of two weeks, westarted with a lecture but as we went on, that's when I realized the purpose of the bridge."

"When we started the project, I said, this is boring… Is this all we will do? I already know this. Then my interest, my interest came in about engineering. I then said to myself that, 'I like it! I don't want to stop.'"

These commonalities within the narratives of the students clearly exemplified and support our argument that in the preliminary exposure in the program, students displayed extrinsically regulated behaviors (Ryan & Deci, 2000b; Vansteenkiste & Ryan, 2013) due to external motivators:

"We made a bridge project because there's a purpose. In two week-time, we are able to make a bridge like what Jaid said. He is in grade 7 and our age difference is far, but we are able to build a bridge to be friends. We became friends and we became a part of each other's life in those two weeks."

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Integrated Regulation

The final theme derived to describe the students motivational state towards the program was conscious valuing and regulation as the participants' narratives suggest that they took ownership and embraced the activities with a personal drive. SDT supportive factors in learning environments may result in transformations in motivation from externally regulated forms such as extrinsic motivators and identified regulators to more internalized forms of motivations (Ryan & Deci, 2017; ten Cate et al., 2011). This occurs when individuals begin internalizing external regulators, values, and combines them with their own sense of self (Ryan & Deci, 2017). According to Ryan and Deci (2017) integrated regulation represents the highest external regulation category and is the most autonomous form of extrinsic motivation. Within this specific learning environment, the participants' narratives implied that they began to identify with and embrace the values and intended outcomes of the intervention. As a result, their motivations shifted from externally controlled means to more autonomous and integrated internalization factors:

> "When we started the project, I said, this is boring… Is this all we will do? I already know this. Then my interest, my interest came in about engineering. I then said to myself that, 'I like it! I don't want to stop.'"

> "It's not the food that I want, uhmm [clearing throat] I want to make a bridge because I saw this on social media… and then as we make our project, I enjoyed it already especially my groupmates."

> "I really want to see my progress, how I can make a bridge and how this, things I learn, will help me in the future."

Research Question Two: How Do These Experiences Inform Our Understanding of the Relationship Between These Two Approaches of Learning and Student's Self-determination?

Exploring PjBL and System Thinking on Learners Self-Determination

The theoretical framework, that underpinned our model, namely, a student-centered methodology (PjBL) and a thinking framework (system thinking), were integrated and applied in the learning environment to determine how those principles supported self-determined behaviors in learners. The researchers integrated opportunities for learners' voice and choice, provided scaffolds through expert teacher facilitation and computer-aided supports, within a co-created structure, based on shared values and norms, and solved a meaningful problem of local significance.

The narratives from the respondents about their experiences in the program provided a much clearer picture of how the two approaches complemented each other to enhance the

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learning process. The narratives of the students revealed a strong indication of their motivation to learn from their acquired learning as an output of the program. For instance, one student shared his enjoyment with the program as it provided him with the opportunity to choose and develop his own design and decide on the methodologies or strategies that he could apply in solving the problem. Citing the importance of the experience he stated:

"I enjoyed the project-based program because nakakapili kami ng mga topic at nakakapagdecide sa aming project (The researchers are able to choose topics and decide about our project) …(it) made me feel more encouraged while being engaged on the process of making the project."

Autonomy and Competence Support in PjBL. Autonomy-support assures engagement and quality learning (Reeve et al., 2022; Ryan & Deci, 2017) but feelings of competence, that is, effectance, lead to self-assurance about their acquired learning (Ryan & Deci, 2017). Autonomy, that is voice and choice, provided the learners with opportunities to learn new things, their way. Autonomy-support, therefore, became the driving factor that pushed them to connect, collaborate, and communicate with other students who shared similar interests and skills. Feyzioğlu and Demirci (2021), in their study on science classes, discovered that the students who conduct and initiate their own guided inquiry develop more interest in a task since they organically develop a sense of responsibility in accomplishing the task. Ramnarain and Rudzirai (2020) explained that the participation of students in inquiries that require scientific procedures increased their autonomy in the stages of problem determination, planning (inquiry), and making conclusions.

The activities employed by the researchers in the program connected the students to realistic and practical applications where they could explore implied concepts together. One activity that is worth mentioning is the creation of Thinking Maps which were introduced to the students on day three as a means of conceptualizing how they would solve the problem. They employed this multiple times during the program's duration. The activity started by having the students think and conceptualize ideas on their own until they were able to create a visual map of their thinking relating the factors on what makes a quality bridge. Support was provided by the facilitators only when requested by the participants and based on their formulation of questions (Kim, 2017). The activity culminated in engagement of the different group members to bring their conceptual design to a tangible form, first in a 2D format, then as a digital 3D model, then as a real-life model.

However, the development of autonomy did not go as smoothly as expected. Due to pervasive cultural factors. In the Philippines, learning is primarily teacher centered and the students are typically passive learners. As such, the students initially struggled with working collaboratively after being asked to complete the task on their own:

"At first, The researchers find it difficult to understand things since The researchers are not used to these kinds of lesson and learning. And The researchers ask ourselves, "why bridge instead of other structure?" Until The researchers slowly realize the meaning and the purpose of the bridge. The researchers realized that it has a beautiful focus as to why we are making a bridge. Why The researchers built a structure and why we develop a bridge."

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Index Copernicus Value (ICV) = 77.57

Such struggles are explained by Masouleh and Jooneghani (2012) that the formation of exercising autonomy is never linear. Additionally, Godwin-Jones (2019) explained that the formation of exercising autonomy constitutes different challenges, especially in contexts where autonomous behavior is not an expectation, and sometimes restricts the learner in associating himself and even his thinking to the concept that should be learned. Those challenges in exercising autonomy may act as a demotivator and impede growth. This must be addressed by the educators and program developers alike by just-in-time scaffolding (Kim, 2017).

Relatedness Support and PjBL. Interestingly, the student narratives revealed growth in feelings of relatedness over the duration of the program. As they developed in their understanding about the programs' structure and intended outcomes, they realized the importance of others and relationships was a critical additional layer in becoming authors of their own learning. This shift is evidenced in the reflection provided by another participant:

"My reflection for day 4 is observing and the most important thing I've learned with my team today is having communication with other members, this is my second day because I took an absence for a couple of day. Given that I'm still adjusting, everything changes when they've welcomed me with delight, so it was really helpful. I can apply what I've learned by observing and giving opinions in my everyday life."

He mentioned the critical indicators that made him attached to the program. One is communication and the other is adjustment. Communication and adjustment are two skills supported by project-based learning. The seminal study of Putri and Hidayat (2019) in communication in science classes among elementary school students revealed that the problems posed in science projects allow students to see opportunities to interact and communicate with each other. However, it did not start on a group basis but starts by instilling among the members of the class the critical role of an individual's system thinking on the thoughts that they hope to share with their classmates. Even in the presence of an expert or a teacher, the problem posed by the projects enabled the students to freely communicate their thoughts and address the pressing concerns of the project. The procedures in the PjBL trained the students to convey the knowledge that they have in the form of both oral and written communication.

Systems Thinking and Competence Support. Systems thinking is aligned with SDT, as a wholistic approach in analyzing and examining complex problems. System thinking relies on understanding the interaction among system components and highlights patterns and outcomes that emerge from such interactions, and organically communicates the importance of interconnectedness and belonging (Ackoff & Greenberg, 2008). York et al. (2019) explains that systems thinking helps students develop "higher order thinking skills" and equip them with the cognitive ability to recognize complex, interconnected and interdisciplinary real-world problems. Competence is another overarching theme that was revealed from the narratives of the respondents. As explained by both systems thinking learning and SDT, feelings of competence and effectance result from learner motivation and engagement (Ryan & Deci, 2017).

ISSN: 0976-7797
Impact Factor: 4.843
Index Copernicus Value (ICV) = 77.57

Indicators of feelings of competence is a culmination of the successful facilitation of a learning process that engages the students to be authors of their own learning. The opportunities offered by systems thinking enables the student to become confident in their abilities which may lead to the development of intrinsic motivation. Engaging in systems thinking, including the use of basic system thinking tools, for the duration of the program, the participants learned to visualize and re-examine their thinking from the various visual models they created. Additionally, the act of considering the different factors that may affect the stability and integrity of their bridge, caused the students to analyze their designs and assess the feasibility of their concepts as they tested their product under the guidance and feedback of the invited engineering expert. Positive feedback from the expert about their accomplishments reinforced feelings of competence and newfound aspirations as expressed below:
"The most important things I learned in the past two weeks is system thinking made me realized how big the world is, made me realize how can I expand my learnings in so many things."

Mononen (2017) and Shaked and Schechter (2019) discussed that systems thinking encourages futuristic views about the world by engaging individuals to be part of a system that functions effectively. While the students can see the difficulties in working with complex systems, by creating an autonomy-supportive learning environment with requisite tools for self-directed learning, including appropriate scaffolds, they are challenged to take serious steps and design long-term solutions and actions related to a concern or problem of personal significance. By working towards the accomplishment of a particular task, learners develop aspirations around their importance in improving a system and on becoming part of the new system or its improved organization.

Synthesis

Autonomy-supportive learning environments where students are given choices, tools, opportunities for collaboration, and appropriate scaffolding lead to effective academic (knowledge and skill acquisition), behavioral, and social outcomes. The results of the exploratory methodology elucidated the relationship between autonomy, competence and relatedness and the designed STEM-PjBL with integrated elements of systems thinking model. The narratives of the students revealed a strong and consistent action towards becoming authors of their own learning. Real life experiences and reflective notes allowed the researchers to analyze the respondents' perspectives and unveil the profound complements of the model and SDT, that is, the student's motivation, engagement, and realizations. Consequently, narratives from the students revealed strong patterns or evidence of how applying the concepts they learned about systems thinking impacted their feelings of effectance and mastery:

"'The whole is greater than the sum of its part', the reason why we need to look into the bigger picture and try to solve and observe the surrounding in order to identify the cause and effect, where it is coming from and why is it like that. What if there's a missing part? It's better to look

at the whole than splitting the parts. By all means, it (the system) cannot function without a single part but can survive a whole…"

"I learned about systems thinking, considering the cause and effect, and making a thinking model. It will help my future self to think wider and look at the bigger picture/a bigger perspective. It will help me grow not only for being a person but by being a student too."

Such statements confirm that integrating the elements of systems thinking in STEM-PjBL, as designed in the model, was effective in helping the students structure their thinking while analyzing problems (Ackoff, 1999; Kim, 1999). The provision of the language and visualization tools associated with systems thinking, and their leveraging of the different types of scaffolding (peer, expert, digital) embedded in the model (Kim et al., 2018) enabled a paradigmatic shift in how the students' approached solving problems in a way that was non-prescriptive, autonomous, and self-directed. As a result, their statements were indicators that they: (1) felt competent in applying their newly acquired knowledge, (2) remained engaged during the program, (3) found deeper meaning in the concepts they were learning, (4) would transfer the strategies in their daily life outside of the classroom, (5) valued the agreed shared-vision of how to operate in a cooperative learning environment and adhered to its requirements. Interestingly, the idea of cooperation and collaboration surfaced as an important element in their learning. Collaborating to solve a problem, relevant to their daily lives, maximized their ability to make sense of what they currently learned and accomplished together towards their future. The gradual formation of competence, through group collaboration, along with just-in-time feedback and scaffolding (Kim et al., 2018) appeared to strengthen the students' autonomy as they began to internalize what they were learning to see themselves as critical thinkers, problem-solvers, effective communicators, and a successful future.

Limitations

While our results indicate that integrating systems thinking in PjBL is a promising strategy for supporting learners' satisfaction of their basic psychological needs, our program was limited in several areas. The researchers were limited by funding as the researchers undertook financing of the project from our personal finances with some donations from family and friends. This impacted the sample size and the duration of the project since it included feeding all the participants daily. Additionally, limited funding impacted the quality and number of materials the researchers could supply for the artifact construction. Better quality materials may have diversified the designs and permitted demonstrations of complexity attributed to the application of systems thinking leading to higher levels of effectance.

The researchers were also impacted by the time the researchers were allowed to interact with the participants within an already restricted implementation timeframe. Access to the students, shifts in participants' schedule due to planned and unplanned school activities, and participant illness presented challenges and disruptions. The participating teachers also pointed out that language was a limitation even as one of the main facilitators used translanguaging

ISSN: 0976-7797
Impact Factor: 4.843
Index Copernicus Value (ICV) = 77.57

strategies (Vogel & Garcia, 2017) during the implementation in an effort to bridge the language gap. The students expressed being uncomfortable with speaking English to accommodate the non-Tagalog speaking facilitator which is not typically expected. Future iteration would support a more culturally sustaining approach by equipping local teachers to implement the program.

Last, one student exited the program early citing work commitments, however, that student was seen on the school campus many days during the program's implementation. Given what the researchers know about the student, the researchers believe that future iteration of the program must have embedded support for neurodivergent learners.

Conclusion

A STEM-PjBL with integrated elements of systems thinking is a promising model for supporting the increase of self-determined behaviors in learners. The narratives, experiences, challenges and opportunities revealed by the respondents on both STEM-PjBL and systems thinking align with the principles of SDT with specific alignment to the major conceptual tenets of autonomy, competence, and relatedness as described in the metatheory. The categories that emerged from the experiences of the students after their exposure to the bespoke PjBL and systems thinking model were engagement and an internal drive to perform, realization of capabilities, and self-affirmation of learning. These all support the idea of the formation of the SDT indicators in student-centered and structured learning environments. The participants showed growth in satisfying their basic psychological needs for autonomy, competence, and relatedness.

The results of the narratives related to autonomy was congruent with the conceptual exploration purported by Banerjee and Halder (2021) on the role of motivation in developing learners' autonomy as influenced by the teacher's ability to provide sufficiently challenging and rigorous learning activities in environments that are non-demanding or controlling (Ryan & Deci, 2017), and the importance of critical exploration with sufficient support (Kim et al., 2018). Gagné et al. (2022) emphasized the role of challenges and "uncertainties" in shaping interdependence and collaboration among learners, and the seminal study of Kaur & Noman (2020) posits that the outputs of self-determined learners are engagement, persistence, effort and a futuristic perspective towards career, the learning process and self-improvement. Furthermore, Nshimiyimana and Cartledge (2020) state that student-centered teaching practices help the formation of self-determination and competence through intentionally selected learning materials, challenging activities, probing questions, and guided and scaffolded instructions all of which were embedded in the model's design.

Recommendations

Given the experience with the program and the expressed limitations, the researchers conceived some next steps and recommendations. Future iterations should facilitate an experimental research approach to include a larger sample size comprised of intervention and

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comparison groups over a longer duration including a component that allows equipping local teachers with pedagogies based on the model to implement and sustain the program independently. Funding should also be apportioned to create student opportunities to explore their competencies in STEM after learning through the model and a longitudinal follow-up for each implementation. Lastly, future implementation should consider other variables that were not included in the study such as: academic performance, STEM identity, neurodiversity support, and artificial intelligence scaffolding as a part of technology-aided support.

References

1. Abu-Ghuwaleh, M., & Saffaf, R. (2023). Integrating AI and NLP with project-based learning in STREAM education. https://doi.org/10.20944/preprints202306.0848.v1
2. Ackoff, R. L. (1999). Transformational leadership. *Strategy & Leadership, 27*(1), 20-25. https://doi.org/10.1108/eb054626
3. Ackoff, R. L., & Greenberg, D. (2008). *Turning learning right side up: Putting education back on track*. Pearson Prentice Hall.
4. Azer, S. A. (2005). The qualities of a good teacher: how can they be acquired and sustained? *Journal of the Royal Society of Medicine*, *98*(2), 67-69. https://doi.org/10.1177/014107680509800211
5. Banerjee, R., & Halder, S. (2021). Amotivation and influence of teacher support dimensions: A self-determination theory approach. *Heliyon*, *7*(7). https://doi.org/10.1016/j.heliyon.2021.e07410
6. Barron, B. (2006). Interest and self-sustained learning as catalysts of development: A learning ecology perspective. *Human Development*, *49*(4), 193-224. http://life-slc.org/docs/barron-self-sustainedlearning.pdf
7. Belias, D., Koustelios, A., Sdrolias, L., & Aspridis, G. (2015). Job satisfaction, role conflict and autonomy of employees in the Greek banking organization. *Procedia-Social and Behavioral Sciences*, *175*, 324-333. https://doi.org/10.1016/j.sbspro.2015.01.1207
8. Boggiano, A. K., Flink, C., Shields, A., Seelbach, A., & Barrett, M. (1993). Use of techniques promoting students' self-determination: Effects on students' analytic problem-solving skills. *Motivation and Emotion*, *17*(4), 319-336. https://doi.org/10.1007/BF00992323
9. Braun, V., & Clarke, V. (2019). Reflecting on reflexive thematic analysis. *Qualitative research in Sport, Exercise and Health*, *11*(4), 589-597. https://doi.org/10.1080/2159676X.2019.1628806
10. CAST (2018). Universal Design for Learning Guidelines version 2.2. Retrieved from http://udlguidelines.cast.org
11. Charmaz, K. (2006). *Constructing grounded theory: A practical guide through qualitative analysis*. Sage.
12. Charmaz, K. (2014). *Constructing grounded theory*. Sage.
13. Chandrasekaran, S., Littlefair, G., & Stojcevski, A. (2015, September 20-24). The role of the facilitator in a project/design-based learning environment [Conference session]. 2015 International Conference on Interactive Collaborative Learning (ICL), Firenze, Italy. https://doi.org/10.1109/ICL.2015.7318224
14. Cheon, S. H., Reeve, J., & Song, Y. G. (2016). A teacher-focused intervention to decrease PE students' amotivation by increasing need satisfaction and decreasing need frustration. *Journal of Sport & Exercise Psychology*, *38*(3), 217-235. https://doi.org/10.1123/jsep.2015-0236
15. Creswell, J. W., & Poth, C. N. (2018). *Qualitative inquiry and research design: Choosing among five approaches*. Sage Publications.
16. Darmawan, A. (2020). The influence of project-based learning-STEM model on student learning outcomes. *Jurnal Pena Sains*, *7*(2), 113-119. https://doi.org/10.21107/jps.v7i2.6443
17. Deci, E. L., & Ryan, R. M. (1991). A motivational approach to self: Integration in personality. In R. A. Dienstbier (Ed.), *Nebraska Symposium on Motivation*, 1990: Perspectives on motivation (pp. 237-288). University of Nebraska Press.
18. Deci, E. L., Vallerand, R. J., Pelletier, L. G., & Ryan, R. M. (1991). Motivation and education: The self-determination perspective. *Educational Psychologist*, *26*(3-4), 325-346.
19. Deci, E.L., & Ryan, R. M. (2000). The "What" and "Why" of Goal Pursuits: Human Needs and the Self-Determination of Behavior. *Psychological Inquiry*, *11*(4), 227-268. https://doi.org/10.1207/S15327965PLI1104_01
20. Feyzioğlu, E. Y., & Demirci, N. (2021). The Effects of Inquiry-Based Learning on Students' Learner Autonomy and Conceptions of Learning. *Journal of Turkish Science Education, 18*(3), 401–420. https://doi.org/10.36681/tused.2021.81

21. Gagné, M., Parker, S. K., Griffin, M. A., Dunlop, P. D., Knight, C., Klonek, F. E., & Parent-Rocheleau, X. (2022). Understanding and shaping the future of work with self-determination theory. *Nature Reviews Psychology, 1*(7), 378-392. https://doi.org/10.1038/s44159-022-00056-w

22. Goodman, M. (1997). Systems thinking: What, why, when, where, and how. *The Systems Thinker*, *8*(2), 6-7. https://thesystemsthinker.com/systems-thinking-what-why-when-where-and-how/

23. Godwin-Jones, R. (2019). EMERGING TECHNOLOGIES Riding the digital wilds: Learner autonomy and informal language learning. 23, 8-25. https://doi.org/10125/44667

24. Kaur, A., & Noman, M. (2020). Investigating students' experiences of Students as Partners (SaP) Investigating students' experiences of Students as Partners (SaP) for basic need fulfilment: A self-determination theory perspective for basic need fulfilment: A self-determination theory perspective Partners (SaP) for basic need fulfilment: A self-determination theory perspective. *Journal of University Teaching & Learning Practice 17*(1). https://ro.uow.edu.au/jutlp/vol17/iss1/8

25. Kim, D. H. (1999). *Introduction to systems thinking*. Waltham, MA: Pegasus Communications. https://tinyurl.com/bdcwjhkh

26. Kim, N. J. (2017). *Enhancing students' higher order thinking skills through computer-based scaffolding in problem-based learning*. Utah State University. https://digitalcommons.usu.edu/etd/5488

27. Kim, N. J., Belland, B. R., & Axelrod, D. (2018). Scaffolding for optimal challenge in K-12 problem-based learning. *The Interdisciplinary Journal of Problem-based Learning*, *13*(1), Article 3. https://doi.org/10.7771/1541-5015.1712

28. Krajcik, J. S., & Shin, N. (2014). Project-Based Learning. In R. K. Sawyer (Ed.), *The Cambridge Handbook of the Learning Sciences Cambridge Handbooks in Psychology*, (pp. 275-297). Cambridge, UK: Cambridge University Press. https://doi.org/10.1017/CBO9781139519526.018

29. Krockover, G., Pekarek, R., Riggs, C., & Shepardson, D. (2000). How well do multiage intermediate classrooms foster successful learning for children? *The Educational Forum*, 64(1), 67–74. https://doi.org/10.1080/00131729908984727

30. Masouleh, N. S., & Jooneghani, R. B. (2012). Autonomous learning: A teacher-less learning! *Procedia - Social and Behavioral Sciences*, *55*, 835-842. https://doi.org/10.1016/j.sbspro.2012.09.570

31. Merriam, S. B., & Tisdell, E. J. (2015). *Qualitative research: A guide to design and implementation*. John Wiley & Sons.

32. Miller, E. C., & Krajcik, J. S. (2019). Promoting deep learning through project-based learning: A design problem. *Disciplinary and Interdisciplinary Science Education Research*, *1*(1), 1-10. https://doi.org/10.1186/s43031-019-0009-6

33. Mononen, L. (2017). Systems thinking and its contribution to understanding future designer thinking. *The Design Journal*, *20*, S4529-S4538. https://doi.org/10.1080/14606925.2017.1352949

34. Lavi, R., Bathe, M., Hosoi, A., Mitra, A., & Crawley, E. (2021). The NEET ways of thinking: implementing them at MIT and assessing their efficacy. *Advances in Engineering Education*. https://files.eric.ed.gov/fulltext/EJ1316272.pdf

35. National Research Council. (2011). *Assessing 21st century skills: Summary of a workshop*. The National Academies Press.

36. Nshimiyimana, A., & Cartledge, P. T. (2020). Peer-Teaching at the University of Rwanda-a qualitative study based on self-determination theory. *BMC Medical Education, 20*(1). https://doi.org/10.1186/s12909-020-02142-0

37. Paris, D., & Alim, H. S. (2014). What are we seeking to sustain through culturally sustaining pedagogy? A loving critique forward. *Harvard educational review*, *84*(1), 85-100. https://doi.org/10.17763/haer.84.1.982l873k2ht16m77

38. Papert, S. (1991). Situating constructionism. In I. Harel & S. Papert (Eds.), Constructionism (pp. 1-11). Ablex Publishing. https://pirun.ku.ac.th/~btun/papert/sitcons.pdf

39. Putri, S. U., & Hidayat, S. (2019). The effectiveness of project-based learning on students' communication skills in science. *Journal of Physics: Conference Series, 1318*(1). https://doi.org/10.1088/1742-6596/1318/1/012006

40. Ramnarain, U. D., & Rudzirai, C. (2020). Enhancing the pedagogical practice of South African Physical Sciences teachers in inquiry-based teaching through empowerment evaluation. *International Journal of Science Education, 42*(10), 1739-1758. https://doi.org/10.1080/09500693.2020.1778810

41. Reeve, J., Ryan, R. M., Cheon, S. H., Matos, L., & Kaplan, H. (2022). *Supporting students' motivation: Strategies for success*. Taylor & Francis.

42. Ryan, R. M. (2000). Peer groups as a context for the socialization of adolescents' motivation, engagement, and achievement in school. *Educational Psychologist*, *35*(2), 101-111. https://doi.org/10.1207/S15326985EP3502_4

43. Ryan, R. M., & Deci, E. L. (2000a). Self-Determination Theory and the Facilitation of Intrinsic Motivation, Social Development, and Well-Being. *The American Psychologist*, *55*(1), 68-78. https://doi.org/10.1037/0003-066X.55.1.68

44. Ryan, R. M., & Deci, E. L. (2000b). Intrinsic and extrinsic motivations: Classic definitions and new directions. *Contemporary Educational Psychology, 25*(1), 54-67. https://doi.org/10.1006/ceps.1999.1020

ISSN: 0976-7797
Impact Factor: 4.843
Index Copernicus Value (ICV) = 77.57

45. Ryan, R. M., & Deci, E. L. (2002). An overview of self-determination theory: an organismic-dialectical perspective. In E. L. Deci, & R. M. Ryan (Eds.), Handbook of self-determination research (pp. 3-33). Rochester, NY: University of Rochester Press
46. Ryan, R. M., & Deci, E. L. (2009). Promoting self-determined school engagement: Motivation, learning, and well-being. In K. R. Wenzel & A. Wigfield (Eds.), Handbook of motivation at school (pp. 171-195). Routledge/Taylor & Francis Group
47. Ryan, R. M., & Deci, E. L. (2017). *Self-determination theory: Basic psychological needs in motivation, development, and wellness*. Guilford Publications.
48. Resnick, L. B. (1987). 1987 AERA Presidential Address: Learning in school and out. *Educational Researcher*, *16*(9), 13-20. https://doi.org/10.2307/1175725
49. Sawyer, R. (2014). Introduction: The New Science of Learning. In R. Sawyer (Ed.), *The Cambridge Handbook of the Learning Sciences* (Cambridge Handbooks in Psychology, pp. 1-18). Cambridge: Cambridge University Press. https://doi-org.access.library.miami.edu/10.1017/CBO9781139519526
50. Senge, P. M. (2006). *The fifth discipline: The art and practice of the learning organization*. Broadway Business.
51. Shaked, H., & Schechter, C. (2019). Systems Thinking for Principals of Learning-Focused Schools. *Journal of School Administration Research and Development, 4*(1).
52. Shenton, A. K. (2004). Strategies for ensuring trustworthiness in qualitative research projects. *Education for Information*, *22*(2), 63-75. https://www.pm.lth.se/fileadmin/_migrated/content_uploads/Shenton_Trustworthiness.pdf
53. Slade, S., & Griffith, D. (2013). A whole child approach to student success. *KEDI Journal of Educational Policy*, *10*(3), 21-35. https://doi.org/10.22804/kjep.2013.10..003
54. Stefanou, C., Stolk, J. D., Prince, M., Chen, J. C., & Lord, S. M. (2013). Self-regulation and autonomy in problem- and project-based learning environments. *Active Learning in Higher Education*, *14*(2), 109-122. https://doi.org/10.1177/1469787413481132
55. ten Cate, O. T. J., Kusurkar, R. A., & Williams, G. C. (2011). How self-determination theory can assist our understanding of the teaching and learning processes in medical education. AMEE guide No. 59. *Medical Teacher, 33*(12), 961-973. https://doi.org/10.3109/0142159X.2011.595435
56. UNDP. (2020). *The next frontier: Human development and the Anthropocene*. Human Development Report 2020. New York: UNDP. Retrieved 29 April 2023 from https://hdr.undp.org/system/files/documents/hdr2020overviewenglishpdf_1.pdf
57. Vansteenkiste, & Ryan, R. M. (2013). On Psychological Growth and Vulnerability: Basic Psychological Need Satisfaction and Need Frustration as a Unifying Principle. *Journal of Psychotherapy Integration*, *23*(3), 263-280. https://doi.org/10.1037/a0032359
58. Vogel, S., & García, O. (2017). *Translanguaging*. Oxford University Press. https://doi.org/10.1093/acrefore/9780190264093.013.181
59. Wang, Moore, T. J., Roehrig, G. H., & Park, M. S. (2011). STEM Integration: Teacher Perceptions and Practice. *Journal of Pre-College Engineering Education Research*, *1*(2). https://doi.org/10.5703/1288284314636
60. Yin, R. K. (2011). *Qualitative research from start to finish.* The Guilford Press.
61. York, S., Lavi, R., Dori, Y., & Orgill, M. (2019). Applications of Systems Thinking in STEM Education. Journal of Chemical Education, 96. https://doi.org/10.1021/acs.jchemed.9b00261

