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Influence of Design Thinking in Integrated STEAM Inquiry-Based Learning on Primary School Students' Empathy and Confidence

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Abstract: *This study explores the impact of integrating design thinking into STEAM inquiry-based lessons on the development of empathy and confidence among primary school students. Students of grade 5 from a school for the underprivileged were taught integrated STEAM through inquiry-based design challenges for three months. This study focuses on the potential of the Design Thinking process within STEAM to enhance empathy and confidence among students. They exhibited high collaboration levels, effective communication, and problem-solving abilities. The design thinking process fostered empathy by making students consider user perspectives. The implications highlight the importance of explicitly teaching empathy and providing real-world examples during the design thinking process to help students understand and prioritize human needs. This dynamic approach transforms learning, making it engaging, relevant, and reflective of the real world. Design thinking in integrated STEAM lessons is a promising approach to enhancing empathy, confidence, and problem-solving skills in primary school students.*

Key Words: Design Thinking, STEAM Education, Empathy, Confidence, Inquiry-Based Learning

Introduction

Teaching and Learning in the 21st century prioritises subjects related to science and technology in educational programs (Kelley & Knowles, 2016). The rapidly changing world and educational contexts demand the students to address local as well as global issues. Interdisciplinary education is a research-informed method, which makes it possible to equip primary school learners with the opportunities to be equipped to face the challenges of the rapidly changing world. Integrated STEAM education (from its acronym for Science, Technology, Engineering, Arts, and Mathematics) has been highlighted as an appropriate educational approach to address these contemporary challenges (Huang, 2022; Silva-Hormazábal & Alsina, 2023). Integration of STEAM subjects helps develop skills, knowledge, and attitudes among the students enabling them to solve current and future problems. It helps promote problem-solving, communication, creativity, critical thinking and social skills among the students (Brown & Brown, 2017; Huang, 2022; Stehle & Peter-Burton, 2019; Wagner, 2008;).

Design thinking is a pedagogical approach which helps the students to understand the problem, other people's perspectives, and their needs, brainstorm ideas and generate creative solutions through developing and testing prototypes (Cook & Bush, 2018). Design thinking in the context of STEAM

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Education helps develop learning content, context and experiences for the students which are relevant to the real world, focused on problem-solving and provide enriching hands-on activities through collaboration(Noel & Liu,2016; Henriksen & Mehta, 2019). The design thinking process in STEAM education can be an effective process for developing empathy among the students (Bush et.al., 2022; Md Hashim, Aris, & Chan 2019; Maiorca et al., 2020). This study is an attempt to explore the influence of the design thinking process within STEAM inquiry lessons towards developing empathy and confidence among students.

Objective of the Study

The objective of the study was to explore the influence of design thinking in STEAM inquiry-based lessons in the development of empathy and confidence among grade 5 students.

Research Questions

The major research questions that guided this study are:

Research Question 1: Does Design Thinking in integrated STEAM inquiry-based lessons help in developing empathy among students in grade 5?

Research Question 2 Does Design Thinking in integrated STEAM inquiry-based lessons help in developing the confidence of students in grade 5?

Literature Review

Recent research reports that the design thinking process prioritises human needs and thus places a strong emphasis on empathy. It emphasises the importance of empathy while discussing the different stages of the design thinking process and uses real-world examples to establish connections. Teaching students to grasp other peoples' perspectives, and understanding the needs of the users helps increase the likelihood of creating useful and effective solutions (Bush et.al.,2022; Etherington,2011).

The Young Foundation includes confidence and relationships among those capabilities which have been demonstrated to lead to positive life outcomes. Youth well-being consists of several interdisciplinary dimensions which include positive education and social-emotional learning (Ng et al., 2019). Evidence indicates that the implementation of effective interventions can enhance social and emotional skills and achieve positive outcomes for adolescents (Clarke et al., 2015).

Empathy and confidence are important aspects of mental health which can be developed among children through positive interventions and schools provide the ideal forum for this. (Kagstrom et.al, 2023; Rampazzo et al., 2016). Non-cognitive skills of students include confidence and empathy and can be developed through school-based social-emotional learning programmes (Gutman & Schoon, 2013). School-based programmes have shown consistent outcomes in positively impacting students' development in areas of social and emotional competencies (Clarke et al., 2015). In order for adolescents to perform well in their future lives, they need to acquire qualities of empathy and confidence (Chae & Kim, 2016; Pâniş oară et al., 2019). STEAM activities which use 'design thinking' help such students to develop these traits (Alrubail, 2015).

Design thinking activities using STEAM bring students together to construct practical solutions in their path to solving challenges in the real world. Students working together with other students is a gateway for the expression of empathy. Researchers emphasise that students should be taught to understand and relate to each other's emotions, particularly those which have positive energy. From communicating with team members to planning out the solutions, relating with the perspectives of peers through empathy can help everyone reach their shared targets. Empathy is evoked through Design Thinking as it allows people to understand the needs of others when experimenting with solutions (Tikkanen et al., 2022).

Students can achieve success if they are able to see themselves as capable problem-solvers. The ability to self-assess one's capability stems from the exposure to experiences of both successes and failures. This belief in one's confidence can therefore be developed through STEAM activities which provide students with such experiences (Chae & Kim, 2016). Past research indicates that STEAM activities do indeed have a positive effect on feelings of empathy and confidence (Zhan, Yao & Li, 2022). One such study's findings show that students participating in a Design

Thinking workshop show reasonable improvements in students' confidence. (Gieras, 2022)

Hence, design thinking used in STEAM activities is significant to aid adolescents in learning empathy and confidence which are important in determining success.

Background of the Research

The current study is linked with a three-year research project focused on Integrated STEAM Pedagogy. The project is being conducted on a chain of schools for the underprivileged, being run by a non-governmental organisation. The broader aim of the research project is to integrate the various components–of Science, Technology, Engineering, Arts and Mathematics (STEAM) in elementary schools through the utilisation of low-cost materials

Method

The current research is rooted in the qualitative paradigm and is descriptive in nature. A descriptive case study method of an in-depth study of a person, group or situation was used by the researcher.

Profile of the Participants

Students of grade five, from a school for underprivileged children being run by an NGO were the participants of the study. The students were all from the lower income strata and could not afford to pay for their schooling. The school was also situated near a slum where they dwelled. A total of twenty-eight students, 10 girls and 18 boys, participated in the study spanning a period of three months.

Research Instruments

Students' confidence and empathy were observed through self-developed rubrics, with four levels. The rubric for confidence had three indicators, viz. behavioural, verbal, and nonverbal. For empathy behavioural, design and verbal indicators were observed. A semi-structured interview protocol was also utilised to gain more in-depth information about the variables being explored.

Data Collection

The students were exposed to a STEAM inquiry challenge of some scientific theme each month, based on the design thinking model. This was focused specifically on creating interest in their studies. It was also the ulterior aim to make the students realise the relevance of what we study in school to their real lives. The discussions based on the theme of the design challenge were held in their respective subject classes throughout the three weeks, underpinned by the design thinking model. During this duration, the students also attempted theme-related worksheets on Science, Mathematics, Social Studies and Languages. The final week of the month was dedicated to the design challenge activity. The children's responses were observed and recorded by the researcher in all the classes where discussions were integrated with the theme of the design challenge. A rubric and a checklist constructed by the researcher were utilised for measuring confidence and empathy at the time of each design challenge. The rubrics outlined four levels based on the following indicators for measuring confidence; behavioural, verbal and non-verbal. Similarly, the rubric to investigate empathy had four levels based on indicators such as behavioural, verbal and design indicators. Furthermore, the students' responses from the Social Studies and Language worksheets were also recorded to gather empathy and connection. Besides using rubrics, interviews of students working in groups were also conducted during and after the design challenge by using a semi-structured interview protocol.

Data Analysis

Observation data from the rubrics is reported according to the corresponding level of each indicator in the rubrics, so as to ascertain the confidence level and empathy of the students for each design challenge. The responses from the worksheets were gathered, coded and then analysed thematically. Similarly, responses from the interviews were transcribed, coded and analysed thematically. The responses are not reported for each of the three design challenges but for the overall experience after three months of intervention.

Integrating Design Thinking in STEAM as the Intervention

In this study, the Arts component of STEAM encompassed Arts and Humanities. Students of grade five in the school were taught various science concepts

through integration with other STEAM subjects by utilising the Stanford design thinking model. This study spans the course of a three-month intervention carried out in a school for underprivileged children. The design challenge activities used in the intervention period included building ramps, sun-blocking structures and exploring solubility & filtration in solutions. Table 1 elaborates on how the Stanford design thinking model was utilised in the study.

Table 1

Integration of Design Thinking in STEAM Pedagogy

Building Empathy	For each design challenge, the students were expected to make a connection and explore various contexts. This helped create a relevance as to why that topic should be studied, as well as empathy and a deeper connection. This was done through the A or the Arts component of STEAM, by integrating concepts and making connections through Social Studies, Language Arts (Urdu and English) and Art. This was carried out throughout the three weeks.
Identifying the Need	Based on the empathy that was created, teachers brainstormed the need for ramps, sun-blocking structures and solutions. This was done during their classes in Science, Arts and Mathematics.
Ideation	This phase was utilised during the last week when students were provided with low-cost material where they were given the Design Challenge utilising the inquiry approach. They had to produce creative ideas for producing original and innovative solutions and models.
Prototyping	The students were given the freedom to choose materials of their liking and asked to build two prototypes in groups of five. A prototype is a scaled-down version of the model.
Testing	While prototyping and also once the models were complete, the groups tested their models and recorded their findings on the record sheets.

Each month the students had a different scientific inquiry. The first one was designing ramps linked with their science lesson on Forces and Motion, in the second month the challenge was to design sun-blocking structures and visors, linked with weather and in the third and final month they explored solubility & filtration, linked with solutions and materials. The integration of the Design challenge theme of making ramps with other subjects after studying Forces and Motion is elaborated as a sample in Table 2 below.

Table 2

Sample of Integration of STEAM in Inquiry-Based Design Challenges

Theme	Science	Technology	Engineering	Arts	Mathematics
Designing Ramps	Forces and Motion	Use simple technology, such as measuring tapes etc. to investigate, explore themes, and document learning.	Build safe Ramps of varying heights, inclines and materials using low-cost materials	*Art:* Design and beautify ramps. *Social Studies:* Identify why and where ramps are required *Language Arts:* Discuss the need for ramps and attempt comprehension task	Explore angles, Measure the height of the ramp with rulers, incline with a protractor, and distance travelled by small toy cars

Results and Findings

This section reports the key findings of the study, which are presented thematically. The findings are based on the observations made through the rubrics and semi-structured interviews. The following themes and sub-themes emerged from the analysis of data which are presented below.

Observation and Interview Responses for Confidence

Confidence was evaluated through the rubrics based on the following indicators; behavioural, verbal, and nonverbal.

Behavioural Indicators

None of the students were hesitant to try new things or unwilling to take risks and explore new material during the design challenge. Only two students from one group were unwilling to try new designs and needed some encouragement from their teachers. All the others showed their eagerness to try new materials for their prototypes. The groups exhibited a high level of collaboration. Each group was given a choice to choose the materials required for the design challenge. They were also explained that they don't need to take excessive materials and could ask for more when required. It was observed that the groups mutually decided on the materials required in consultation with their peers. The designs were also decided in collaboration. However, in each group, there were children who took the lead. All the participants in the groups exhibited a willingness to share ideas. Moghal, Kazi, Usman and Saeed (2020) also report that group work in design thinking in STEAM improves confidence and collaboration.

When asked how confident they felt when asked to try something new all the students expressed enthusiasm and confidence. One of them, (S4) expressed, "I wanted to explore new materials and designs when making the sun-blocking structures." One student stated, " Having the freedom to pick the resources we wanted for our model, made us feel confident" (S20). Another group of students expressed "We all decided we want a more shaded space for our bus stops and designed that."

Non-verbal indicators

Most of the students demonstrated particularly good eye contact during the teaching phase as well as the inquiry-based design challenge. Their body language was engaged, and enthusiastic. They did not seem to get distracted or lose interest. There were very few signs of restlessness or lack of interest among the students. These were witnessed when the prototypes were being decided, on which resource material to be used. Some children took the lead during the ideation stage and model building. They remained focused on the challenge. Those who were not actively involved or taking the lead in building the prototypes assisted their peers in one way or another. Overall, in each group, at least two children took the lead and others collaborated.

Verbal indicators

When asked to explain their choice of materials and designs, from the entire class of twenty-eight, seven students had difficulty expressing their thinking process regarding their choice of materials and the design they chose. Of these, five could explain their thoughts without any prompting. All the others explained the design thinking process and articulated ideas in their native language, clearly and concisely. They could ask and answer thought-provoking questions and provide feedback to peers in a constructive way. They asked relevant questions while filling out their record sheets and recorded their findings with ease. When they found themselves unable to express something in writing due to a lack of correct expression or spelling, they sought their teachers' assistance.

During the interview, all the students said they felt excited to do something new. They had never been involved in something like this and were not reluctant to explore. When asked how they felt they reported "curious, excited, fun and interested." Some even said, "Happy not to be reading and writing." One boy was very expressive and said that he used to do all the household chores with his mother. He elaborated "For the first time I have felt we study something that is useful for us in our life. I do not want to learn things; I want to do things. I enjoy doing things" (S5).

When asked if they were scared to make a mistake, some of the students, both male and female students, said they were a little unsure but not scared.

They reported not being clear about what they were expected to do initially. However, once they understood the inquiry process, they became comfortable. Most of the students also reported that they were happy to explore without having to focus on memorization of terms, definitions, and concepts. They expressed that they felt confident that they would be able to design what they had discussed. A few students also said they were confident they understood the underlying concept but were still shaky when it came to formal tests. When expressing their feelings while working with others on a team project, they said they felt more confident because they felt a team member could help in case they were stuck. When asked to explain about a time when they tried something new and it did not work out, and what this experience taught them, students gave mixed responses. Few reported, "I wanted to blame my team members (S15), and wanted to start from scratch again (S7)". On the other hand, some group members reported "We all quickly discussed what the possible mistake was and came up with a solution." One child said, "I realised how important it was to keep the group together all the time (S21)."

Observation and Interview Responses for Empathy

Empathy was evaluated through the rubrics based on the following 3 indicators; behavioural, design indicators and verbal indicators

Behavioural indicators

The rubrics reflected students' connection with the design at four levels. The first one was where they did not consider the needs of the users when making design decisions. The second one reflected some consideration of needs, but they may need some help from the teacher or their peers. At the third level, students' design considers the needs of the users, and they can explain how these needs have informed their design decisions. At the highest level, they reflect and actively seek out feedback from the users or stakeholders and use this feedback to improve their design.

Design indicators

The four levels of the rubric for the design indicators were made with the focus on assessing whether, through the Design Thinking STEAM project, students are better equipped to reflect on the needs or perspectives of the users or stakeholders. It ranged from not-at-all-clear understanding and deep understanding with connections to the community. Students mostly responded at levels two or three. During the design challenge for force and motion, students of a group designed a double road ramp using different materials. They felt the cyclists would be better off on a different surface which would add safety to their journey. A student stated; "Our group ramp model has two roads and we have used different surface materials for each road. One side of the ramp is for cars and the other is for cycle riders, so that they can ride safely" (S12). Yet another group reported they wanted to design a ramp specifically for children in wheelchairs, so they could also enjoy themselves in the playground.

Verbal indicators

The indicators on the rubric to observe verbal indicators for empathy ranged from being unable to explain the different perspectives of the users, to being able to explain the different perspectives of the users or stakeholders of their STEAM project clearly and concisely and being able to articulate how these perspectives informed their design decisions.

The different groups of students working together were observed discussing the need for the design in the context of their user. When designing the ramps, one group made a bridge as a ramp. They used two textures, one for regular cars, and another "safer material" for cyclists. Another group made a ramp for a park. They also made lamps on the sides, so that people could have access at night as well. Similarly, sun-blocking structures were designed for bus stops, parks, and house terraces, catering to the needs of different stakeholders.

Students were also asked if they could explain the design thinking process in their own words. It was noted that when this question was asked after the first design challenge cycle, children started off by mentioning the ideation phase. They had to be reminded how the lesson began by making connections. Then only they were able to connect with the first stage, empathy. They made remarks such as "Oh that was just a discussion," "That was not a part of studying," and "How is that the first part of the

lesson?" However, once it was explained they became more motivated and connected. They even produced contextual answers and connected the use of ramps in driveways, hospitals etc. One student said, "I have an aunt in my neighbourhood and she uses a wheelchair. When she goes outside and there is no slide for her wheelchair, she faces a lot of difficulties entering that place." (S26). In the second round, the connections were noticeably clear. Each group designed sun-blocking structures after an in-depth discussion and needs analysis. Similarly, in the inquiry related to solutions, they could differentiate between soluble and insoluble substances, express the need for filtration and relate it to their daily life. A student stated, "On hot days we students crave a Rooh Afza drink (red syrup and water drink) as soon as we reach home. It is a solution, made of soluble solute mixed in water." (S2) Another student added, "Lemonade is also a solution. It is made of sugar, water and lemon. Tasty, gives strength and is very commonly used in my neighbourhood during the summer season"(S10). One student highlighted the usage of filtration as "The water they get from the public water source at times contains dirt and debris. A basic water filtration plant, would assist the community in removing the sediments from the water before using it" (S9)

Discussion and Conclusion

The results from the observations and interviews suggest that confidence and empathy are essential components of the design thinking process. The majority of the students were eager and confident to try different materials for building their models. Material selection was mutually decided by the students in groups. They exhibited a high level of collaboration and willingness to share ideas. As the students are required to work together to solve the problem, it promotes collaboration and teamwork among them. This collaboration helps develop confidence, communication, cooperation, sharing of ideas, respect for each other's viewpoints and other social skills among the students. This resonates with the work done by Ertas (2021) and Gunduz (2019) who reported that as design thinking provides students with the opportunity to be creative, solve problems, and receive support from their peers, they become confident. The majority of the students were also able to verbally explain their choice of materials and design they had made. All students felt excited about the design challenge activities and learned along as they performed the activities. Not being judged for mistakes, memorising content and having peer assistance made them feel more confident. This finds support in the study done by Ogunleye and Owolabi (2018), where peer support during the design thinking process, helped students to become confident.

The design thinking process encourages students to understand the needs of others. Developing a deeper understanding of people helps make them empathetic. Having empathy while carrying out the design challenge activities also assists the students in understanding how the user will interact with the model, and product made. Initially, few students were able to understand others' perspectives while making design decisions. However as they progressed through the design challenge activities, they were able to consider the needs of the user. This resonates with the work done by Huang et al. (2022), and Vogel and D'Arcy (2022) that empathy is developed among students when they learn to recognize and comprehend others' needs.

With little assistance from peers, they even tried to explain how it informed their design decision. Likewise, improvement in students' ability to verbally explain the different perspectives of the users and make connections was also observed. Ajayi and Ogunleye (2017) highlighted that design thinking in STEAM inquiry activities makes the students consider the needs and perspectives of others, collaborate with each other and communicate ideas clearly to find solutions.

The study concludes that Design Thinking in integrated STEAM inquiry-based lessons have the potential to foster empathy and confidence among the students, develop problem-solving and social skills and improve the overall learning process. Greater empathy was demonstrated when the students understood and connected with the experiences and perspectives of others. It promotes critical thinking, meaningful problem-solving, and useful and contextual innovation. It is hoped that continued use of this method will promote not only human-centric thinking, but also pro-social perceptions, and motivate students to pursue STEAM as a career (Kijima, Yang-Yoshihara, & Maekawa, 2021).

Implications for Teaching and Learning

- Teachers can use the five stages of design

thinking to:

- Assess their students' progress by observing how they perform at each level of design thinking.
- Identify students who need more support and those who are ready for more challenging tasks.
- Develop appropriate learning activities that are tailored to the needs of their students. For example, teachers can provide more support and guidance to students who are struggling, and they can provide more opportunities for independent work and leadership to students who are demonstrating deeper understanding.
- They can also change the grouping of children for each design challenge.
- Explain the design thinking model explicitly while teaching, particularly empathy so that students learn to form connections between
- The design thinking process prioritises human needs and thus places a strong emphasis on empathy. Teachers should emphasise the importance of empathy while discussing the different stages of the design thinking process and use real-world examples to establish connections. Opportunities to practise empathy with others should be provided to the students. Teaching students to grasp other peoples' perspectives, and understanding the needs of the users help increase the likelihood of creating useful and effective solutions. Students are able to develop essential skills and knowledge, shaping their learning experience through using problem-solving and hands-on activities. They are encouraged to think critically to solve the problem and design creative solutions. This makes learning dynamic, engaging and relevant to them.

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