Every Step You Take, I Will Be Watching Over You:

Leveraging Remote Patient Monitoring using Internet of Things

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Abstract

Remote patient monitoring (RPM) faces several adoption barriers, including technological challenges. However, two critical factors hindering its widespread implementation are patient engagement and developers' understanding of patients' needs. Studies have demonstrated that empathy is essential in the requirements gathering process. Empathetic developers are better positioned to comprehend and address the specific needs and challenges faced by patients and healthcare providers. This paper presents a teaching case focused on designing and conducting a Requirements Engineering (RE) course. During the course's design and execution, two key research questions emerged: (RQ1) How can we guide practitioners in RPM projects to achieve motivation and engagement in the process? (RQ2) How can we increase developers' empathy and understanding of patients' needs? The paper offers a case study of a course addressing these questions, demonstrating that by engaging developers in the process, they gained increased awareness and understanding of patients' needs. The course's approach highlights the importance of fostering empathy among developers to create RPM solutions that effectively cater to the specific requirements of patients and healthcare providers.

Keywords

Remote patient monitoring, Internet of things, User centered design, Motivation theories

1. Introduction

Remote patient monitoring (RPM) is a method of healthcare provision that employs digital tools to gather and send health information from patients in their own settings to medical professionals for examination and evaluation [10]. It enables healthcare professionals to monitor and manage patients' medical conditions remotely, without requiring physical visits to healthcare facilities. There are several factors hindering the adoption of RPM, technological and psychological: Some patients may struggle with using the technology or adhering to the monitoring protocols consistently, which can limit the effectiveness of RPM [2]. However, here is evidence that collaboration among stakeholders involved in RPM design and implementation, along with common understanding of the benefits, enhances the chance of a successful RPM project [3].

In this context, Internet of Things (IoT) technology significantly underpins the effectiveness of RPM systems by leveraging interconnected devices equipped with sensors and actuaries. These devices collect real-time health data, which is crucial for continuous monitoring and management of patient health. IoT's role in RPM facilitates timely medical interventions and personalized care, crucially improving patient outcomes and healthcare efficiency [7].

Another researched area in the context of designing RPM systems is empathy. Described as "think

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and feel oneself into the inner life of another person" [5, p82], empathy is considered as one of the most important core skills for engineers today. Research has shown that empathy plays a crucial role in the requirements gathering process. Developers who possess a high level of empathy are better equipped to understand the perspective of patients and healthcare providers, enabling them to identify and prioritize the most critical requirements [15].

This paper presents a teaching case of designing and teaching Requirements Engineering (RE) course. While designing and executing this course, the following research questions arose: (RQ1) How can we guide practitioners in RPM projects, to achieve motivation and engagement in the process? (RQ2) How can we increase practitioners' awareness towards the different stakeholders of the RPM system, and their role in the project?

1. Background and Related Work

2.1 Remote patient monitoring (RPM)

Remote patient monitoring (RPM) is a healthcare delivery approach that utilizes digital technologies to collect and transmit patient health data from their location to healthcare providers for review and analysis [10]. This innovative method of delivering care has gained significant traction in recent years due to advancements in technology and the increasing need for accessible, cost-effective healthcare solutions. Numerous studies have highlighted the potential benefits of RPM for patients, healthcare providers, and healthcare systems:

1. Improved patient outcomes: RPM enables early detection of health issues and timely interventions, leading to better management of chronic conditions and reduced hospitalization rates[1,5].
2. Increased patient engagement: RPM empowers patients to actively participate in their care, fostering self-management and adherence to treatment plans [5].
3. Enhanced access to care: RPM extends healthcare services to remote and underserved areas, improving access to care for vulnerable populations [4].

2.2 Internet of Things

Internet of Things (IOT) is a network of physical objects ("things") embedded with sensors, software, and other technologies for the purpose of connecting and exchanging data with other devices and systems over the internet [8]. The use of IoT in RPM requires implementing a system which incorporates interconnected devices equipped with sensors and actuators to collect and transmit patient data in real-time [11]. This data, encompassing vital could be used to provide actionable insights. By facilitating continuous monitoring, IoT can enable healthcare providers to make informed decisions, offer personalized care, and intervene proactively, thereby preventing complications and hospital readmissions [18]. Early attempts to use Internet of Things in RPM were conducted in recent years. For example, the use of MQTT protocol sensors in [12], bearing promising results. An additional attempt, using wearable devices, was conducted in recent years [8].

2.3 User Centered Design

User-centered design (UCD) is a design philosophy and process that places the needs, preferences, and limitations of end-users at the forefront of product development. While the principles of UCD are widely acknowledged in the field of design, research suggests that awareness and adoption among practitioners can vary significantly. A study by Harte [8] found that while most practitioners were familiar with the concept of UCD, there was a lack of consistent understanding of its specific methods and practices. The study highlighted the need for better education and training initiatives to bridge this gap and ensure effective implementation of UCD principles. Interestingly, a study by Hussain et al. [9] revealed that practitioners often perceive UCD as a time-consuming and costly process, which can hinder its adoption. However, the study also highlighted the potential benefits of UCD, such as improved product quality, user satisfaction, and long-term cost savings, which could help mitigate these perceived barriers. Researchers have also investigated strategies to enhance practitioner awareness and adoption of UCD. Venturi et al. [12] proposed a framework for integrating UCD practices into agile software development methodologies, which could help practitioners incorporate user-centric approaches into their existing workflows. Furthermore, Gulliksen et al. (2004) suggested the development of UCD maturity models and assessment tools to help organizations evaluate their current practices and identify areas for improvement. Such tools could also serve as a means of raising awareness and facilitating the adoption of UCD principles among practitioners [16]. Overall, while the benefits of user-centered design are widely recognized, the literature suggests that there is still room for improvement in terms of practitioner awareness and adoption. Ongoing research and initiatives focused on education, organizational culture, and the development of practical tools and frameworks could help bridge this gap and promote the effective implementation of UCD principles in practice.

2.4 Motivation Theories

Several cognitive theories address the topic of encouraging motivation for work tasks. Here we briefly present two theories that relate to personal and group motivation during working tasks.

According to the Theory of Flow [3] there are five elements of reaching to a state where the individual is immersed in the performed task (some of which can be extrinsically induced): Clarity, Centering, Choice, Commitment, Challenge. Sawyer [13] extended these elements to the context of group flow, to contain, among others, the following characteristics: A compelling, shared goal, a sense of being in control, blending egos, equal participation, familiarity, constant and spontaneous communication, and the potential for failure. Though motivation theories were used to enhance RE, a much rigorous process is needed [14]. We relied on these characteristics when designing our course [15], creating an environment that would encourage group flow. The proposed solution is described in the next section.

3. Method

This paper describes a case study of a novel IoT course. The course consisted of both frontal lectures each week, along with class activity related to that week`s subject, inspired by the concepts of flow and group flow theories (see Table 1). The course was held in the software and machinery departments and consisted of 34 last year software engineering students and one mechanical engineering student. The students learned various issues in contemporary RE, and designed a working prototype, focusing on building a smart sensor-based system for physical therapy rehabilitation. The students focused on two types of devices: a rehabilitation walker, and a parallel with an obstacle.

Table 1 elaborates the class lectures and activities. The activities are analyzed using motivational elements from flow and group flow theories:

Table 1

Course schedule

Week	Class lecture	Class activity (Motivational elements)
1	• Intro to RE • data elicitation • Inclusive RE • Lab tour	Team forming, project definition (Flow – Choice, Commitment, Challenge)
2	Design thinking workshop	Designing IoT prototype for a handicapped patient (Group flow – Collaboration)
3	• Cloud computing, • Alternative handling	Defining project cloud architecture and alternatives (Group flow – Collaboration, constant and spontaneous communication
4	• Taxonomy • guest lecture – the rehabilitation story of a veteran	Learning taxonomy using the candy task, defining taxonomy for the project; Lab hours working with the controllers (Group flow – Potential for failure)
5	• Software Architecture and risks • peer review	Peer-reviewing prototypes of their peers, defining project architecture and risks (Flow – centering Group flow - blending egos, equal participation)
6	• Technical debt, • cognition and motivation	Defining cognitive and motivational factors of project success (Flow – Choice)
7		Final presentations

In the first week, we discussed in general what is RE. The students divided into teams, and had a tour to the lab, where they had a demonstration of the devices, so they could define the scope of the project .

In the second week, each team had a design thinking workshop, according to the conducted two short interviews with physiotherapists and staff in the patients in a rehabilitation process. department, according to [1]. The students strived to find knowledge gaps in the current RE process. In the following lecture, findings were analyzed. Next, the students had a homework assignment, where they designed a survey intended for rehabilitated patients, based on the conclusions from the interviews. We spent several meetings refining the questions, conducting pilot sessions and final refinement, until reaching the final draft of the survey.

The following lesson aimed to deeply motivate the students and foster their understanding by bringing in a guest speaker. This individual, who had survived severe injuries, shared his journey from the traumatic event, through extended hospital stays and battling PTSD, to his current state.

In the following lectures, the students practiced models for RE. Each lecture and between lectures, they added their contributions, individually or collaboratively. At class work, every week one of the students acted as a facilitator, hence, responsible for the progress that week.

From the second week on, we dedicated the last 3 hours of the day to hands-on sessions, where they worked with the IoT devices: installed controllers and sensors, designed solutions and printed 3D models, and complementary tasks needed for the project (See Figure 1).

Next, after a brief lecture on taxonomy, students engaged in the "candy task" - categorizing different candy types first by characteristics of their choice, then in a matrix. Teams struggled with the task, achieving varied results. The following collaborative task was to write a project glossary, choose a taxonomy structure, explain it, and create a diagram. This was done in a shared Google Doc and presented to the class and lecturer for feedback. The last week dealt with cognition and motivation theories, and implementations for motivational elements for their project.

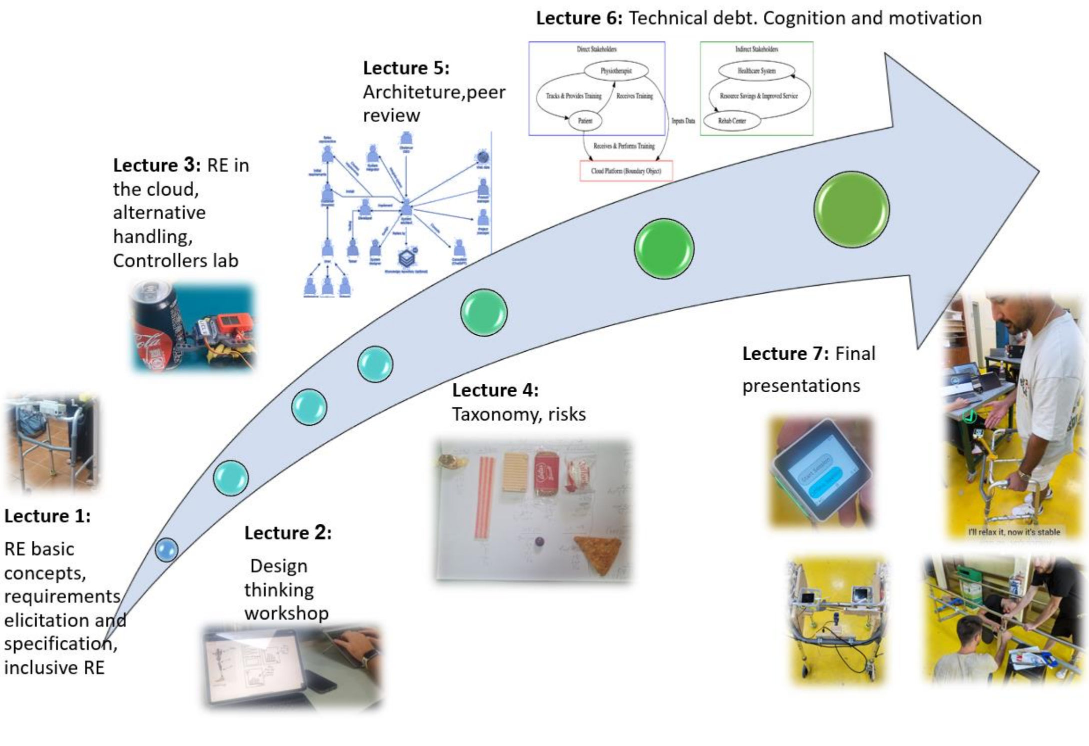

Figure 1. Course schedule and intermediate byproducts

To facilitate seamless communication and collaboration, we established a WhatsApp group where students could openly discuss their progress, share updates on their efforts to engage stakeholders in completing the survey, and report on their advancements in the collaborative modeling task outside of lecture hours. Additionally, we conducted weekly office hours, providing each team with the opportunity to seek guidance and consultation from us regarding both the technical and design aspects of their respective projects.

4. Findings and discussion

Throughout the course, we observed a high level of motivation among the students, both at the individual and group levels, as they tackled the intensive task. This strong motivation was evident in the students' quotes, which highlighted their enthusiasm, dedication, and sense of ownership in the project.

We will address student behaviors and perceptions with regards to our research questions. RQ1 – Motivation and engagement of the students:
Throughout the course, the students exhibited engagement and motivation:

- Active participation: All students demonstrated a strong commitment to the course by attending every lecture (with an 80% mandatory attendance policy) and actively engaging in all class activities. Moreover, when collaborative work was required, the students exhibited a high level of cooperation and collaboration, as evidenced by their reflections.

- Motivation to complete home assignments: Three out of seven students went above and beyond the required number of interviews, and all students provided detailed reflections. When asked to distribute a survey to at least 30 students, every student actively participated in sharing the survey on designated social media and WhatsApp groups. They expressed great satisfaction upon receiving numerous responses to the survey. When tasked with analyzing survey results, all students conducted thorough qualitative and quantitative analyses of the responses.

- Dedication to project deliverables: The students invested an extensive amount of time and effort in researching, designing, building, and testing their project deliverables. Many students even used their personal credit cards to purchase specialized components and materials for constructing fully functional prototypes (with only one student requesting a refund). They spent long hours, often working into the evening, in the machine shop manufacturing custom parts with extreme precision. The students also demonstrated unwavering dedication to programming and debugging the complex control systems.

- Leveraging social media and digital tools: The software students heavily relied on digital collaboration tools to coordinate their project. They created a dedicated WhatsApp group to facilitate constant communication, share updates, ask questions, and troubleshoot issues in real-time. Google Drive served as their central repository, housing shared folders containing all project documentation, code repositories, wireframes, and design mockups. This setup allowed every team member to easily access and contribute to the latest files from any location. The students also frequently utilized link sharing to distribute relevant resources, research papers, API documentation, and example projects for scrutiny and inspiration.

- Self-learning new technologies: Several teams needed to mount sensors and controllers on healthcare accessories. Through self-learning, they acquired the skills to use Onshape (See Figure 3), a collaborative CAD system, and designed and 3D-printed mounting brackets and adapters.

In the last week of the course, students were asked about their experience. Table 2 presents interesting quotes, which demonstrate both empathy for different stakeholders of the RE system (staff and junior students), and characteristics of both flow and group flow theories.

Table 2

The RE task from the students' perspective – analyzed using motivation theories

Qoute	Flow	Group flow
"It was inspiring to work on our own project and I wanted to dedicate the entire time of class for that"	✓	
As for the rest, I was required to work with technologies that I am less familiar with and I had to learn specific uses of them for the project, this was a big departure from the comfort zone.	✓	
Yes, I learned to be more accepting of the opinions and criticism of others.		✓
It was necessary to research the issue of disabilities for which we provided a solution	✓	
As for the rest, I was required to work with technologies that I am less familiar with and I had to learn specific uses of them for the project, this was a big departure from the comfort zone.		✓

RQ2 – Students' awareness to RPM special needs and requirements:

We noticed that students developed awareness towards inclusive populations' needs, at several points in the course: design thinking workshop, requirements specifications, and post-course questionnaire.

In the design thinking workshop, they focused on inclusive design, in particular - developing application for handicapped individuals. They had several different ideas: guidance for visually impaired, smart prothesis, augmented reality guidance (Figure 2):

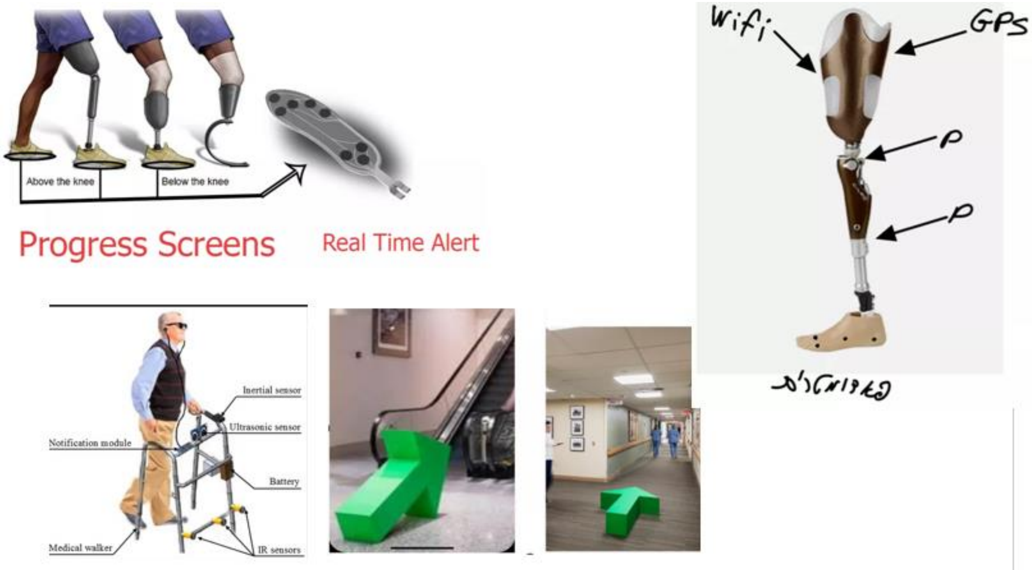

Figure 2. Design thinking workshop prototypes

The design thinking workshop played a crucial role in setting the foundation for this empathetic approach. By engaging in activities such as user interviews, persona creation, and empathy mapping, the students were able to step into the shoes of the patients and gain a more comprehensive understanding of their needs, challenges, and aspirations. This immersive process allowed the students to move beyond a purely technical perspective and consider the human factors that are essential to creating truly inclusive and user-centered solutions. As the students progressed through the specification and design phases, they continued to build upon this foundation of empathy. The collaborative nature of these stages, which encouraged the sharing of ideas and experiences among peers, further reinforced the students' understanding of the problem from multiple viewpoints. This group flow experience fostered a sense of collective purpose and motivated the students to work together towards a common goal of creating a solution that genuinely addressed the needs of the patients.

They invested countless hours on creating the prototypes for the presentations, including self-learning of 3D design and printing (Figure 3):

Figure 3. Final presentations prototypes - intermediate byproducts

Here are some examples of different requirements taken from the projects' final submissions, which highlight the students' awareness of the special needs of the patients:

Non-functional requirements:

- Some interesting requirement types from the works of the students: The system must precisely and reliably measure pressure on the handles to assess weight distribution and symmetry
- The system will contain universal Adaptability treadmill connectors
- Adaptability - The system will include a minimum number of buttons
- Ease of use - The system will include a minimum number of Ease of use button
- The sound of the system will be loud and clear enough for the relevant populations

Engineering requirements:

- The system shall be capable of performing symmetrical pressure measurements on both handles.
- The system must store walking data, including pressure distribution, symmetry indices, and other relevant metrics.
- Pressure Sensor Safety: Design pressure sensors with rounded edges and incorporate a cushioning layer to avoid discomfort or risk of injury.
- Sensors and hardware layer - will include the various sensors such as distance sensors to detect obstacles, motion sensors to track the user. The sensors will be connected to the Im5 core controller which will manage the reception of the data from them.

In the final week of the course, the teams showcased their fully functional prototypes to their classmates and guest lecturers from various departments within the college. The presentations were met with great acclaim and positive feedback (Figure 4).

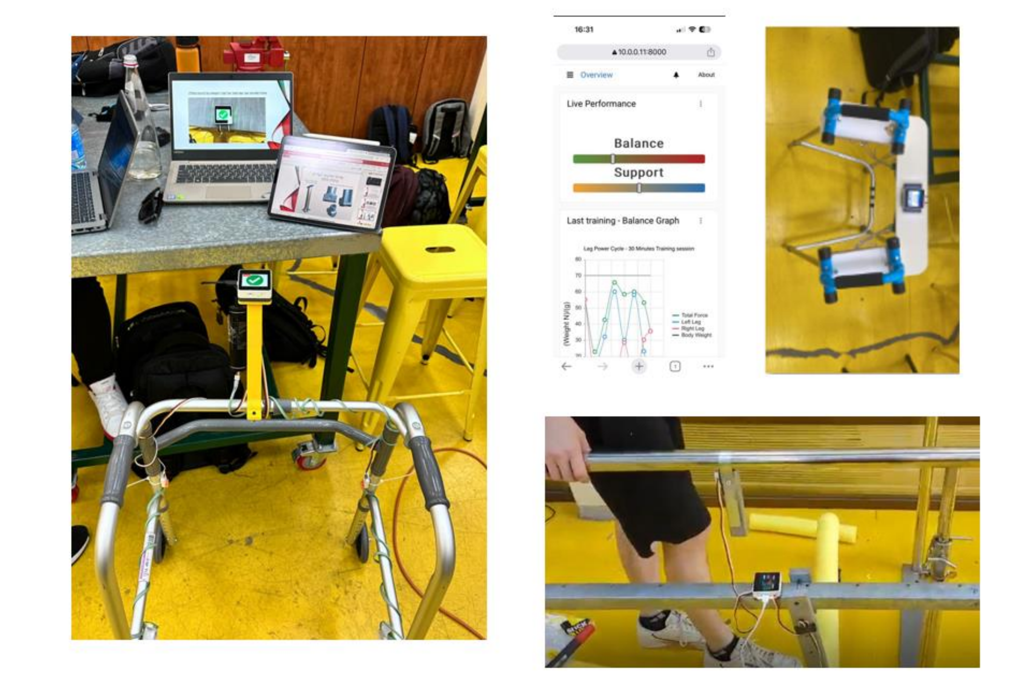

Figure 4. Final presentations prototypes

The students also received a post-course questionnaire if their perception towards inclusive populations had changed. Following are several leading quotes:

- “Yes, I was more exposed to the difficulties of people in rehabilitation that I hadn't thought about before”
- “Yes, I didn't know you could recover from a stroke.”
- “I understood more the day-to-day difficulties of the people of the population I studied and our actions seem simple are actually very difficult for them”
- “Personally, because of the survey we distributed, I learned about the great difficulty experienced by people who are in rehabilitation, dealing with performing exercises and the importance of developing tools that will make it easier for them in the process”
- “Yes, I was exposed to a population that I was not exposed to and aware of its difficulties before”

This heightened awareness of inclusive design and patient needs is a testament to the transformative power of immersive, collaborative learning experiences. By engaging in a design process that prioritizes empathy and understanding, the students were able to develop not only technical skills but also the soft skills and mindsets necessary for creating truly user-centered solutions , as required in these processes [17]. Furthermore, this experience highlights the potential for design thinking and group flow to be integrated into various educational contexts, particularly in fields where understanding and addressing user needs is paramount. By providing students with opportunities to immerse themselves in real-world challenges and collaborate with their peers, educators can foster the development of empathy, creativity, and problem-solving skills that are essential for success in today's complex and rapidly changing world.

In conclusion, the students' journey from the design thinking workshop to the specification and design process, and their reflection on the entire course, demonstrates the profound impact that immersive, collaborative learning experiences can have on developing an awareness of inclusive design and user needs. By prioritizing empathy, focusing on UCD, and understanding throughout the design process, educators can help students develop the skills and mindsets necessary for creating solutions that truly make a difference in the lives of those they serve.

5. Conclusions and future work

This paper presents the findings from a RE class that engaged students in addressing an RE challenge directly relevant to their learning environment. By working on a project that impacted their own department, the students were able to gain a deeper understanding of the needs of various stakeholders within their educational setting. Their familiarity with the existing knowledge processes allowed them to better empathize with these needs, leading to a more comprehensive and nuanced approach to the RE process.

This paper demonstrates the value of engaging students in RE challenges that are directly relevant to their own interests and learning environments. By fostering a strong sense of motivation, empathy, and ownership, such projects can help students develop the core skills and mindsets necessary for success in the field of RE. As educators, we have a unique opportunity to shape the next generation of requirements engineers by providing them with meaningful, engaging, and socially impactful learning experiences. The application of motivation theories, as described in our analysis, further supports the notion that the students demonstrated significant personal and team motivation.

Based on the success of this experience, we recommend that educators consider challenging their students with projects that align with their interests and passions. Such an approach can foster the development of essential skills, including effective group work and empathy. By engaging students in projects that resonate with their own experiences and concerns, educators can create a more meaningful and impactful learning environment.

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