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Board 426: Using the ARCS Model of Motivation to Design 9–12 CS Curriculum

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Using the ARCS Model of Motivation to design 9-12 CS Curriculum

Abstract

This ongoing project provides an overview on the use of the Attention, Relevance, Confidence, Satisfaction (ARCS) model of motivation to design an Internet-of-Things themed curriculum for CS students in grades 9-12. The ARCS framework is used as a conceptual framework to unpack high school students' motivational influences in engineering/computer science project-based learning via a series of focus groups. Using the insights obtained from First and Second cycle coding based qualitative analysis, IoT-based CS curricular modules that align with Grades 9-12 Computer Science Teachers Association (CSTA) standards were developed. The curricular design centered around creating learner-focused scaffolding in project-based learning environments, improving the relevance of the classroom content with the real-world context that students have experiences in or are knowledgeable of, and stimulating intrinsic motivation in addition to extrinsic rewards.

Introduction

This exploratory study aims to develop, implement, and evaluate a novel, scalable, and transferable Internet of Things (IoT) pedagogical ecosystem that provides grades 9-12 students with Computer Science (CS) education. With continued advancement in science and technology comes the need to educate students in emerging technologies to better prepare them for future academic and professional pursuits. The Internet of Things (IoT) is an exponentially rising, transformative field that is bound to positively impact global job markets and industries. In simple words, IoT is the practice of connecting physical devices to the internet for enabling data driven operations and decisions. At its core, IoT involves physical computing – the use of inexpensive microcomputers that run highly optimized code to collect, analyze, and share data with other devices and/or a cloud server. Human users or computer algorithms can access this data using dashboards or software Application Programming Interface (API) calls.

Background

IoT Education Background

The integration of hardware, software, real-time data, software processes, and human interaction makes IoT a valuable platform for teaching CS topics in a hands-on manner [1]. This is particularly useful when introducing CS principles to students in grades 9-12, due to the emphasis on physical computing and the availability of user-friendly programming languages such as Python and NodeMCU/LUA [2]. These modern programming languages lower the barrier to entry for 9-12 grade CS students. IoT-based curricula can use learning frameworks that incorporate a combination of computing devices and instruments to convert abstract computer programming concepts and theories into practical, experiential knowledge [3]. Readers are referred to [1] and its references for a comprehensive review of the IoT educational landscape.

ARCS Model

The ARCS model of motivation proposed by Keller is a structured framework used in instructional design to address student motivation [4]. It is based on the expectancy-value theory and focuses on four dimensions of student motivation: attention, relevance, confidence, and satisfaction. The model provides a framework for educators to understand and address students' stimulation levels in an educational environment. The dimensions in the ARCS model refer to obtaining and sustaining student interest (attention), meeting personal needs or goals (relevance), self-perception to succeed (confidence), and reinforcing accomplishment with internal and/or external compensation (satisfaction). The model has been used in various studies to assess student motivation and educational interventions [5], [6]. It is argued that addressing student motivation is critical to ensure student engagement in student-centered instructional approaches [7], [8], and is important for elective educational programs in which students self-select [9], [10].

Using ARCS Model in The Context of IOT Education

A total of 32 students from four high schools located in four different US states participated in six focus groups administered online. To ensure that a diverse range of high school settings were represented, purposeful sampling was employed, encompassing various types such as suburban, urban, and rural high schools. Of the 29 participants who responded to the demographics survey, 69% identified as men (n=20), while 31% identified as women (n=9). Regarding racial/ethnic identity, 41% identified as White/Caucasian (n=12), 34% identified as Black/African/African American (n=10), 10% identified as Asian/Asian American (n=3), and the remaining 15% identified as having multiple or diverse racial/ethnic identities. Specifically, 3% identified as both American Indian/Native American and White/Caucasian (n=1), 3% identified as both American Indian/Native American and Black/African/African American (n=1), 3% identified as both White/Caucasian and Black/African/African American (n=1), and 3% identified as Hispanic/Latino(a) and Black/African/African American (n=1).

Guided and interactive discussions were conducted through focus groups, which were conducted online, to gather insight into students' motivation in engineering/computer science project-based learning. The focus group sessions began with a brief introduction of the study, and students were asked to create pseudonyms to maintain confidentiality and complete an anonymous survey. The focus group protocol was based on the ARCS model, which was audio-recorded and transcribed for analysis and reference. Questions revolving around student's attention, relevance, confidence, and satisfaction were made. Appropriate Institutional Review Board (IRB) approvals were obtained for this study.

The focus group transcriptions were analyzed using first and second cycle coding methods [11]. First Cycle coding methods involve developing an initial round of codes to build a thorough list of codes representing the dataset. Second Cycle coding methods are more analytical and involve developing categories that synthesize first cycle codes based on conceptual similarity. In the first cycle, in-vivo coding was used to develop an initial codebook. The codes were labeled using the letters from the ARCS acronym and overarching themes were synthesized to underscore the emergent subfactors in relation to the ARCS model factors. Using the codebook, second cycle coding was used to combine codes into groups based on conceptual similarity. Two researchers engaged in the coding process to ensure interrater reliability and trustworthiness of the findings [12].

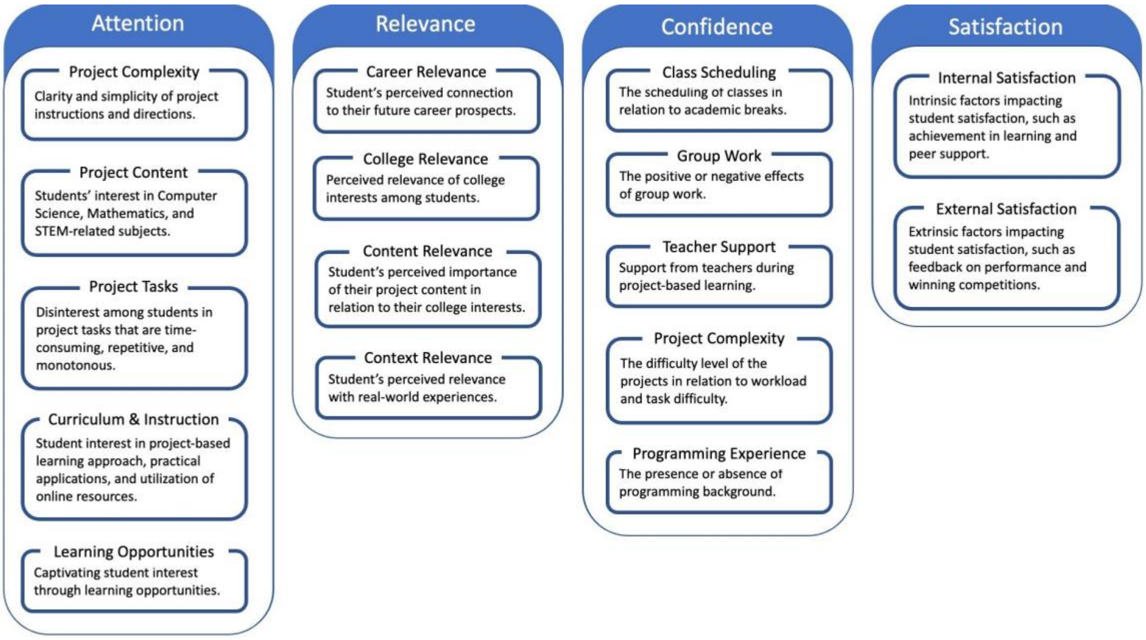

Figure 1: Summary of Findings

Findings

The emergent ARCS factors and subfactors from the qualitative analysis of the focus group data is noted below. The summary of findings is presented in the Figure 1.

Attention

The study found that students showed higher attention and interest in project-based learning when the projects were simple and straightforward, with clear instructions. The students responded with enthusiasm to the computer science, mathematics, and engineering aspects of the projects, and most preferred to work in groups. The students reported that projects with real-world applications were more engaging and stimulated their curiosity to learn more. They also favored hands-on activities and interactive learning.

Relevance

The relevance of the students' projects was found to be significant in several aspects: Career Relevance, where students made connections between their projects and their future career interests; College Relevance, where students recognized how their project experience would prepare them for college and be useful to their college experience; Content Relevance, where students found the content of their projects aligned with and useful to their personal interests, although some students struggled with the connection between the programming tasks and real- world applications; and Context Relevance, where students identified connections between the project content and personal or real-world scenarios, finding the content personally relevant to their day-to- day life.

Confidence

The study found that teacher and peer support can impact students’ confidence in programming. Students who had teacher support or positive experiences with peers generally felt more confident. Students who had prior programming knowledge and experience were more confident compared to students with little to no experience. Reference materials, presented in either offline or online formats, were noted to enhance student confidence to work through a task. Project complexity and the level of explanation on math integration was shown to impact students’ confidence, with more complex projects enhancing confidence, but also potentially overwhelming students. Class scheduling was also found to play a role in confidence, with mandatory school breaks hindering students’ performance and confidence.

Satisfaction

Students in the study reported internal satisfaction from exposure to new topics and developing new skills, as well as a sense of autonomy and the ability to help classmates. External satisfaction was also reported when students received positive performance feedback, such as good scores or winning a competition. Negative performance feedback resulted in dissatisfaction and affected their class experience.

Curricular Modules Using The 4-Layer IOT Model

The 4-layer model of IoT is a conceptual architecture that consists of four key dimensions: real-world sensing, communication networks, software services, and user interfaces. This model was proposed by Da et al. in [13] and has been widely adopted in the field of IoT technologies. When viewed through the lens of IoT/STEM education, this model allows educators to design curriculum and pedagogy in a multi-disciplinary manner while incorporating technical and societal challenges associated with IoT. The curricular modules of this study leveraged the experiential component of IoT devices with the software concepts of programming. Modules were designed around programming IoT sensor hardware with a modern computer programming language. The introductory version of these modules has been detailed in [14]. The curricular activities were aligned with the standards outlined by the Computer Science Teachers Association (CSTA) in the areas of algorithms and programming, computing systems, data and analysis, impacts of computing, and network and the internet [3].

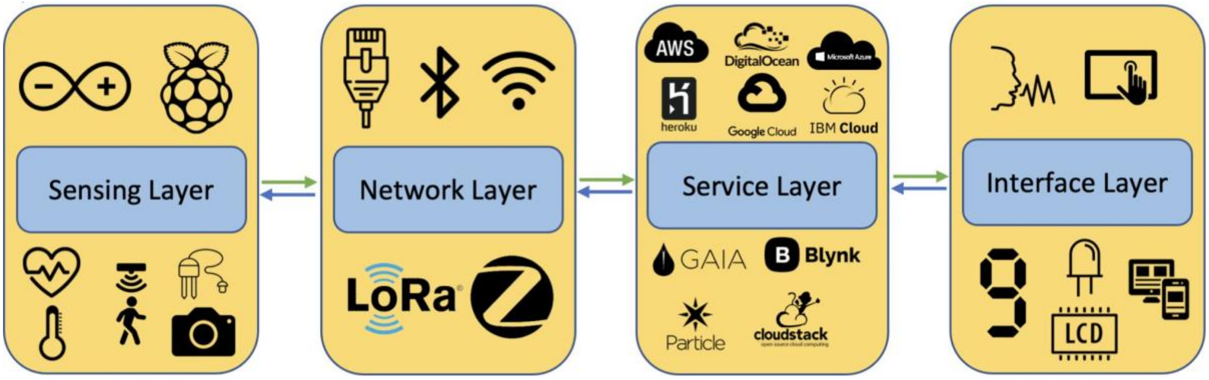

Figure 2: The IoT 4-layer architecture encompassing IoT systems [1]

Python Module

In the Python module, the students were introduced to the Python 3 programming language, a widely popular, interpreted, high-level and general-purpose programming language that is known for its conciseness and ease of readability. The module covers the installation of Python and necessary software, as well as the introduction to several Python Integrated Development Environments (IDEs) with features for code writing, debugging, and data inspection. Students learned the fundamental programming constructs of Python including variables, mathematical operations, input/output commands, conditionals, loops, and lists, which serve as the building blocks for developing their first Python program for IoT sensor hardware. Based on the focus group findings, all assignment problems were based on real-world themes of IoT- enabled smart homes and smart cities.

Sensing Layer Module

In the Sensing Layer module, students were introduced to IoT sensor hardware, which serves as the primary layer in any IoT system and includes sensors embedded in real-world environments. Two categories of sensors, environmental and proximity/motion sensors, were covered using a Python Application Programming Interface (API) for easy interface with the hardware. Each session began with an overview of the hardware followed by a discussion of real-world applications and hands-on coding exercises to interface with the sensors. The students acquired sensor data in real-time and utilized if/else conditions, data averaging, and visualization techniques to display results on the Python console. Key emphasis was put on discussing the real-world implications of sensor technologies as well as important use cases in students’ local communities.

Interface Layer Module

The Interface Layer module focused on the integration of user interfaces within IoT systems. The students learned how to create interfaces for user interaction with the IoT system using hardware displays such as LEDs, LCDs, touch screens, and actuating devices like motors and buzzers. The students used Python programs to create real-time visualizations of the sensor data obtained from the previous sensing layer module. The module also emphasized the use of software interfaces such as dashboards, text-based alerts and prompts, and text notifications with discussions around importance of accessibility for end-users from different demographics.

Network Layer Module

The network layer module covered the theoretical aspects of technologies that enable communication and the exchange of information between IoT elements. The module focused on a basic overview of popular wired and wireless network technologies used by IoT devices and systems, such as Wi-Fi, Bluetooth, Zigbee, and LoRa. The selection of network layer technology for an IoT system was emphasized to require consideration of various factors, such as cost, data rates, ease of implementation, performance, battery life, reliability, and governmental restrictions. This module focused on providing students with relevant context and clear pathways to becoming networking professionals in industry.

Service (Cloud) Layer Module

The service layer module introduced the students to cloud technologies and services. Cloud services play a crucial role in IoT architecture. The module covered theoretical concepts about their function followed by classroom discussions. The students learned about the different cloud service providers like Amazon, Google, Microsoft, IBM etc. and the breadth of services they offer. The assignments involved coding exercises with sensors and actuators to evaluate the students' ability to build sophisticated functionalities using the template Python code provided.

Conclusion

This ongoing effort aims to create a modern, forward-looking CS curriculum based on the use of IoT hardware kits, software APIs, and an active learning-based curriculum. Conducting multiple focus groups and analyzing the data resulted in unique insights that are being used to improve the effectiveness of the curriculum. Future work will focus on implementation of this curriculum across multiple schools and collecting quantitative and qualitative data about student performance, motivation, teamwork, and attitudes.

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