CARES Model for Supporting Computing Education and 4C Framework for Teaching in Hybrid Classrooms

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This article introduces the Computing for Application, Research, Entrepreneurship, and Service (CARES) model for supporting computing education and the Content, Community, Communication, and Collaboration (4C) framework for teaching effectively in a hybrid classroom.

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With the advent of computing technologies, computing education has become increasingly important. While traditional computing education curricula have become more technology-focused, it is necessary to consider these curricula from a broader perspective, particularly from the students' learning and development viewpoint. This article first presents a Computing for Application, Research, Entrepreneurship, and Service (CARES) model for computing education,[1] which explores computing education from a macro perspective. It provides insights for enriching curriculum design to include a core layer and a career/development layer. On the other hand, following the COVID-19 pandemic, hybrid classrooms (that is, simultaneous class sessions composed of in-person and online students) are trending toward a new norm. Thus,

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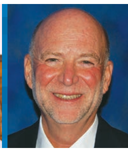

the second part of this article takes a micro perspective of computing education by presenting the content, community, communication, and collaboration (4C) framework.[2] This framework is designed to bolster the hybrid classroom experience.

In summary, this article aims to answer two questions, one from the macro and another from the micro perspective: 1) How can we enrich computing education in particular to take into consideration students' learning and development? 2) How can we more effectively teach in a hybrid classroom setting, taking the fundamental elements of a classroom into consideration?

CARES MODEL FOR COMPUTING EDUCATION: A MACRO PERSPECTIVE

This section explores the CARES model for computing education from a macro perspective. Figure 1 depicts the CARES model. This CARES model provides a novel design to support more engaging computing education. This model has three layers: the core layer ("think"), the course layer ("learn"), and the career/development layer ("develop"), each of which plays a crucial role in the learning and development of computing students.

The core layer of the model focuses on developing two fundamental thinking skills: computational and creative. Computational thinking involves problem-solving using a logical thinking approach. It includes skills like algorithmic thinking, pattern recognition, and abstraction. Creative thinking involves creating new and innovative ideas. Some examples are brainstorming and lateral thinking. Traditionally, computing education has focused mainly on computational or logical thinking. Creative thinking, however, has become increasingly important in computing (for example, developing innovative applications). At the most fundamental level, the ultimate goal of computing education is to endow students with the necessary computational and creative thinking skills.

The course layer of the CARES model addresses the curriculum, covering the knowledge and skills related to computing education. The Association for Computing Machinery/IEEE Computer Science Curricula[3] is a good reference for this layer, as it covers fundamental computing topics, like algorithms, data structures, and programming languages. In addition to traditional teaching, open educational resources should be encouraged for student learning[4] and enrichment. Representative resources include online courses, tutorials, and videos that can facilitate learning outside the classroom.

The career/development layer of the CARES model comprises four major concentration areas: application, research, entrepreneurship, and service.

While traditional computing education curricula have become more technology-focused, it is necessary to consider these curricula from a broader perspective, particularly from the students' learning and development viewpoint.

These areas represent potential career paths for students after graduation.

Application learning focuses on applying knowledge to solve problems. Application is about applying computing knowledge in a specific area, such as working as a programmer in a company.

Research learning seeks to advance knowledge through investigations like designing more efficient algorithms (that is, that can run more efficiently than the existing ones). Research involves advancing knowledge, such as pursuing a Ph.D. or conducting research in a laboratory.

Entrepreneurship learning seeks to realize knowledge by introducing innovative services or products to meet market needs. Entrepreneurship concerns starting a business or joining a startup (for example, developing an e-commerce website to sell innovative products to global customers).

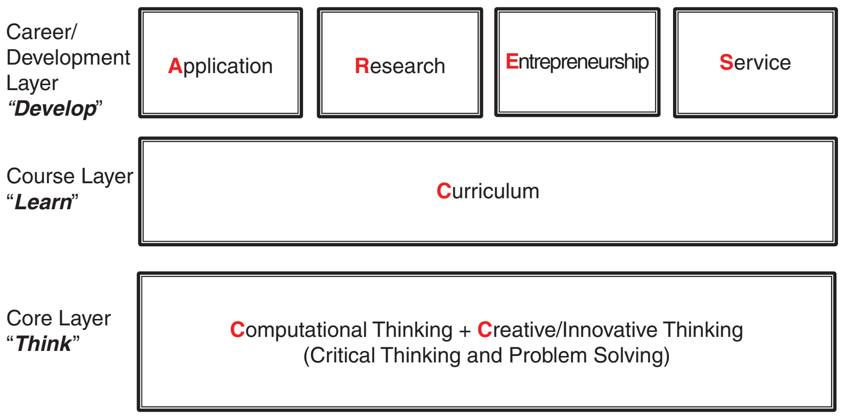

FIGURE 1. CARES model.[1]

Service learning is about serving with experience to offer a service to others without expecting anything in return. Service involves using computing knowledge and skills to serve society, such as working for a charity organization and developing software to help disabled people.

CARES BASELINE DESIGN AND IMPLEMENTATION FOR FIRST-YEAR STUDENTS

This section presents the design and implementation of a project-based learning subject based on the CARES model for first-year students. The approach can be used as an exemplar baseline to design and implement similar subjects at higher collegiate levels.

The application project aims to foster computational thinking and creative thinking. Most first-year students must gain the requisite programming knowledge or experience for a new application project. Hence, choosing a suitable programming tool for first-year students is important. App Inventor[5] helps students rapidly learn how to develop an application. This tool allows students to create mobile apps with a graphical programming interface. App Inventor also reinforces computational thinking. In more traditional programming education, the emphasis is mainly on coding. During the design stage, however, students needed to think about a creative/innovative application design and then define the user requirements by building a concise use case diagram. Next, they needed to implement the design through teamwork. With App Inventor, students develop apps by focusing on the underlying logic rather than program syntax. In practice, one group of students developed a Math Fighter game for children to learn math calculation, and another group created a helpful app to keep track of expenses. The first-year student can learn how to design and implement a basic mobile app through the basic application project. As these application projects are group projects, students also learned about teamwork.

There are two considerations for a successful first-year student research project. First, the design of a relevant project is essential. Second, a suitable tool must be selected for the first-year student with little or no programming experience. As the application project tends to be more system/application-oriented, a data-oriented research project should be designed to provide students with a different computing perspective. With this in mind, students were asked to study different machine learning models for stock price prediction. Orange,[6] a data mining and visualization tool, was chosen for the research tool. Like App Inventor, Orange also provides a user-friendly interface so students can investigate different machine learning models, such as random forest and neural networks, to train data and perform predictions to execute a small research project. This also seeks to facilitate students through the primary research steps: defining a problem, studying related work, and investigating and evaluating a method.

The primary consideration for the entrepreneurship project to focus on first-year computing students, who typically need a more substantial business background, is a practical approach to the business and service aspects of computing. Traditionally, students are asked to complete an entrepreneurship project by writing an extended business plan. Using this approach, students fill in a business plan template where most input only requires rote passive rather than active thinking. The first-year student CARES business project uses a concise C3 Model-Map[1] to address this issue. This tool encourages students to concentrate on thinking about some key business elements. This is the entrepreneur's first and most important step, focusing on three initial core elements: customer, concept, and company. Ultimately leading to a company with people, product, profit, promotion, place, and partnership (6P), the Model-Map seeks to guide students in shaping a business idea, including identifying customer needs, developing a business concept, and outlining a company with all 6P elements. Finally, each group delivers a presentation on their business idea. While they were free to propose business ideas, some students also linked them to their application projects. The entrepreneurship project aims to cultivate students' creative thinking and enhance their writing and presentation skills.

A service element was not incorporated into the first-year student seminar subject, as another subject set the stage for service learning.

Based on the CARES model, the project-based first-year student subject received positive student comments and feedback. In particular, Table 1 shows how the CARES model facilitates students' understanding of the application, research, and entrepreneurship aspects of computing and further fosters both computational and creative thinking. This can better prepare students to study other computing subjects as they advance through the curriculum.

THE 4C FRAMEWORK FOR HYBRID CLASSROOMS

Looking at the micro aspects of computing education learning, we turn to the 4C framework for hybrid classrooms,[2] as shown in Figure 2. The COVID-19 pandemic changed higher education, and hybrid classrooms are now becoming a new norm. Postpandemic, this teaching arrangement of combining in-person and online students in a simultaneous classroom experience has been adopted by many institutions worldwide. To support hybrid classrooms, however, one must rethink some traditional approaches. To address this need, the 4C framework highlights four essential components for effective hybrid classrooms: content, community, communication, and collaboration.

Content is the most fundamental component of the hybrid learning experience. It involves presenting teaching materials, such as slides, videos, and other multimedia resources. In a hybrid classroom, content should be equally accessible to in-person and online students.

A sense of community emphasizes the importance of belonging in a learning environment. In a hybrid classroom, it is important to ensure that in-person and online students feel part of a learning community rather than learning alone. This can be achieved through group activities or exercises.

Communication is essential in an effective classroom so students can ask questions and communicate or interact with others (that is, the teacher or other students). In a hybrid classroom, communication can be facilitated through various channels (for example, chat messages and discussion forums).

Collaboration is also important and closely related to community. In an effective classroom, students should be active listeners and actively involved in learning. For hybrid classrooms, collaborative learning activities can be facilitated through group exercises, discussions, and other innovative means of engaging students.

SHARED EXPERIENCE: TEACHING IN A HYBRID/ ONLINE CLASSROOM

This section highlights the common issues in running hybrid classrooms and offers practical experience in addressing the problems using existing software based on the 4C framework. Many teachers use video conferencing software, like Zoom, to deliver traditional lectures to hybrid class sessions. They often focus on presenting lecture slides as a one-way presentation. This common practice, however, is an expedient way to deliver a lecture in a classroom environment. The 4C framework provides a basis for recreating a "classroom" in a learning-enriched hybrid environment. For content, besides solely relying on lecture slides, there must be other teaching/learning materials in play. There must also be a seamless way to present these materials, including smoothly switching among slides, videos, and websites without the tedious opening and closing applications to show their content. The 4C framework, as shown in Figure 2, demonstrates how Microsoft Teams can seamlessly support a hybrid classroom. During the COVID-19 pandemic, this 4C framework-based arrangement facilitated a hybrid class for the aforementioned CARES-based subject. Teams was launched as the backdrop with a sizable content window to the left and a chatbox to the right. The shared screen allowed in-person and online students to see the same view as the remote students. For the content component, applications such as PowerPoint slides or a Web browser with

TABLE 1. Design of a project-based first-year student seminar subject based on the CARES model.

CARES elements and project nature	Key design principles
Application (group project)	• Using App Inventor as a graphical programming tool for first-year students, thus focusing on logic not syntax • Designing a mobile app using a concise use case diagram and implementing it using App Inventor • Cultivating creative thinking, computational/analytical thinking, and teamwork
Research (individual project)	• Using Orange as a graphical data mining tool for first-year students to explore various machine learning models • Going through basic research steps to investigate stock price prediction by conducting an individual research project • Cultivating computational/analytical thinking, possibly with creative thinking (for example, creative ways to tackle the research problem) • Analyzing and presenting research results
Entrepreneurship (group project)	• Using a concise C3 Model-Map to shape a business idea, possibly linked to the application project • Focusing key business elements: customer, concept, and company (with 6P: people, product, profit, promotion, place, and partnership) • Cultivating creative thinking and analytical thinking • Enhancing presentation and writing skills

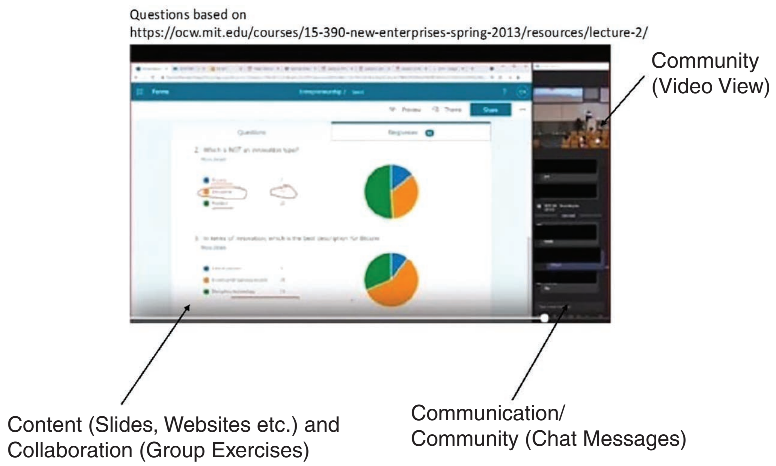

FIGURE 2. The 4C components.[2]

different tabs, were superimposed on the content window. Note that the "Browsed by an individual slideshow" option should be used to adjust the window size flexibly for presenting PowerPoint slides.

Furthermore, related open educational resources, such as videos, were shown through the Web browser (for example, using the 3E framework[4]). The applications must be seamlessly switched via the menu bar, providing smooth transitions. When presenting slides and other materials, annotations should highlight key points. Students found the annotations helpful in maintaining pace with the lecture flow. As mentioned, community feeling is essential in an effective classroom. The community feeling weakens should only lecture slides be presented via video conferencing software.

As shown in Figure 2, the video view of the classroom was displayed in the top right corner to enhance the community element, fostering a sense of engagement. Moreover, group activities were conducted through the content window. For instance, students could answer multiple-choice questions together via their smartphones, or laptops. The collective results were displayed in the content window and were related to the collaboration element.

Communication plays a vital role in a classroom. While verbal communication is commonly used in traditional classrooms, it is more challenging to communicate verbally in a hybrid classroom because of echoes and other acoustic and nonacoustic issues. For the communication component, students preferred communicating through the chatbox, which can be displayed beside the content window. While presenting the slides, the teacher could easily see chat messages and quickly respond verbally so that both online and in-person students could hear the responses.

Collaboration or collaborative learning, exemplified by doing something together for active learning, is an essential element of hybrid learning. Indeed, this critical form of reinforcement is often bypassed in the hybrid classroom. As shown in Figure 2, students can easily carry out group exercises, such as multiple-choice questions or even coediting a file, while their answers are displayed for all to share through the content window.

A student survey was developed to evaluate the relative importance of the 4C components to students, and a five-point scale was ++ for responses, where total agreement was rated 100%. Figure 3 shows the survey results based on whether students strongly agreed or agreed with each component/tool. It reveals that all components are crucial for an effective hybrid classroom. Interestingly, the students rated "Presentation slides" and "Annotations" as the most effective tools, followed by "Chatbox," "Recorded lectures," and "Group exercises." These tools cover all of the 4C components, highlighting their relative importance in a 4C hybrid classroom, as students perceive. Table 2 summarizes the key features based on the 4C model.

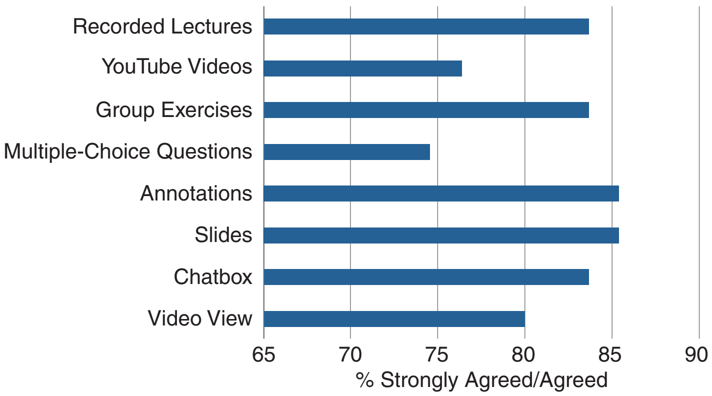

FIGURE 3. Student survey.[2]

TABLE 2. Key features based on the 4C framework.

The 4C elements	Key features
Content	• Presenting slides, videos, websites, and other teaching materials through a common content window • Switching between teaching materials seamlessly through the menu tabs • Using annotations on the whole screen for highlighting slides, websites, and other materials • Recording lectures for student revision
Community	• Displaying a classroom video view • Using a chatbox for community interaction (for example, showing support and emotion) • Doing group-based activities (see collaboration)
Communication	• Student-to-teacher communication through chatbox so that the teacher can see student messages during presentation or while teaching • Teacher-to-student communication through verbal communication (for example, answering a question on a slide) so that both in-class and online students can hear
Collaboration	• Answering multiple-choice questions together • Doing group-based exercises, such as coediting a file with answers showing through the content window

This article describes the mechanisms of the CARES model for computing education from a macro perspective and explores the 4C framework for hybrid teaching from a micro perspective. The former model addresses computing education from a broad visionary approach, particularly considering students' learning and development. The latter framework then addresses some useful techniques to enhance the growing trend toward hybrid teaching. In particular, it considers the fundamental components necessary for an effective hybrid classroom. Combined, the CARES model and the 4C framework provide valuable insights into computing education. C

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