TAF Journal of Advances in Technology and Engineering Research JATER
2022, **8**(1): 24-32

PRIMARY RESEARCH

Interdisciplinary Collaborative Learning with Modular Programming and Information Visualization of Urban Smart Spaces

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Keywords
Interdisciplinary Learning
Modular Programming
Information Visualization
Collaborative Learning
Smart City

Received: 28 February 2022
Accepted: 05 April 2022
Published: 11 June 2022

Abstract
The purpose of this research is for interdisciplinary students, with the theme of smart city space, how to conduct collaborative learning on thinking, identification, and strategies for programming and visualization issues, to develop an intelligent interactive interface between users and environmental data. We have set up an interdisciplinary course on "Interactive Smart Space Design", which combines the fields of interactive design, engineering, electrical machinery, and electronics, trying to introduce unmanned aerial vehicle simulation path, modular programming, and information visualization modules into the course to conduct programming and computational thinking learning, guiding students to conceive and design, and in-depth development of programs and development practices. Finally, analyze and evaluate the learning effect through the work report and Expert assessment. The results show that the modular programming method is more suitable for students with low information ability, and the information visualization performs better in the later stage of the project, reflecting the actual staged division of labour in the industry. The interdisciplinary collaborative learning process can reflect and revise problem points in the process of thematic decision-making, but coordination and division of labour impact team cooperation.

I. INTRODUCTION

A. Interdisciplinary Can Provide Problem-Solving

Due to the changes in the global economic and social environment and the acceleration of technological change, well-known companies worldwide have been prompted to reform engineering education. Like other education fields, engineering higher education needs to find suitable interdisciplinary methods to meet these requirements [1].
Interdisciplinary courses are a promising way for students to learn and apply knowledge from other disciplines [2]. And in line with the world trend, programming teaching can cultivate students' Computational Thinking (C.T.) and problem-solving ability [3]. And transboundary capabilities provide scientists, engineers, and others with the foundation for their ability to solve today's real-world problems [1, 4].

B. Modular Programming

In the past, learning a programming language involved acquiring multiple types of knowledge. Novices must learn syntax, know how to generate programs and develop mental computer system models [5]. On complex parametric models, unstructured parametric schemas lack legibility and incomprehension, which reduces the ability to edit and share models, making collaboration difficult. Research has found that using modular programming is a great way to reduce code complexity, and parametric modelling has a noticeable change in legibility. And the schema function built with the principles of modular programming will ultimately allow designers to understand better [6]. Teachers can

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teach students to learn core programming skills through modular programming, decompose a complex problem into several small pieces, use a programming program to process each piece and integrate the intermediate results of each program to get the final solution. This teaching mode reduces the challenge of computer programming courses [7]. Integrating concepts and modular programming creates a distributed topic-oriented application in a cloud computing virtual integration environment, and the effectiveness of this application is experimentally demonstrated [8, 9].

C. UAV Use for Urban Climate Measurement

In response to climate issues related to the urban heat island effect, it is also applied in smart city living spaces and microclimate measurement across fields. But related subject research students also lack opportunities to experience weather patterns and gaps in the ability to correlate weather knowledge in weather-related contexts [10]. With the rise of Unmanned Aerial Vehicle (UAV) systems, many types of image data, such as high-definition (H.D.) photos, captured video frames, and thermal images, can be collected through different image-sensing technologies [11]. Weather monitoring has also been implemented in smart cities and urban areas through UAVs and sensors, examining air quality in small urban areas and showing trends in Particulate Matter (PM) concentrations about altitude and traffic conditions [12].

D. Information Visualization of Climate Data

The Study indicates that visualizing weather data can communicate short-term precipitation forecasts to the lay public. And to prove the importance of weather data visualization to people's lives [13]. Complex information is visualized and conveyed through the information visualization process to present and process information to users [14]. In addition, building a three-dimensional (3D) visual model by visualizing information about weather processes, hazards, and visual cues can help bridge the cognitive gap [10]. The simultaneous presentation of language and images is conducive to selecting, organizing, and integrating cognitive processing procedures, helping students compare the two and establishing connections [15].

E. The Objective of the Study

Given this, we take the urban smart space as the theme, design modular programming connected to cloud storage, simulate UAV trajectory planning, and can combine climate data to present a dashboard of information visualization. Our goal is to gather students from different departments for collaborative discussion and practice in teams through learning curriculum knowledge, improve the programming skills of design students, and help cross-field learners cross the threshold and achieve learning results through experts' accurate learning strategies and evaluation.

II. METHODOLOGY

A. "Interactive Smart Space Design" Course

The "Interactive Smart Space Design" course is offered in the National Taipei University of Technology (NTUT) microengineering course. According to the number of people and majors, the course divides the design and programming background students into three teams of 4 students and promotes cooperation between design majors and programming majors.

The design of the interactive smart space focuses on the integration of virtual and real. Students can freely set themes for ideas and discussions. Through the division of labour and collaboration, they learn to write programs across disciplines and combine information visualization modules to develop an intelligent interface that allows users to interact with the environment anytime. Information visualization module dashboard, such as Figure 1. The main course structure of the 16-week course, such as Table 1.

B. Thematic Report and Team Self-Assessment

The interactive smart space is designed as an interdisciplinary course, and the team is expected to learn across disciplines through the division of labour and collaboration. Each team can provide the modified parameters of modular programming for code execution according to the set theme. The UAV trajectory can be displayed in dynamic simulation. The interface design of information visualization can also be dynamically presented according to the data, and the theme report can be carried out through the presentation, as in Table 2. The critical points of the report are the thematic results, ideas, and self-assessments on teamwork. This Study organizes this part as research results on teamwork.

C. Expert Assessment

After the course, a comprehensive assessment of the thematic results is carried out by Expert assessment. The experts are all interdisciplinary majors, and the members are composed of three full-time teachers from different departments of interaction, engineering, and electrical engineering, a teacher with an information background and a teacher with a user experience background. In addition to scoring the course scores for various items such as program modi-

ISSN: 2414-4592
DOI: 10.20474/jater-8.1.3

fication and operation, information visualization interface, oral report, and overall performance, each team's modification suggestions and evaluations are the objective bases of this Study for students' interdisciplinary collaborative learning performance.

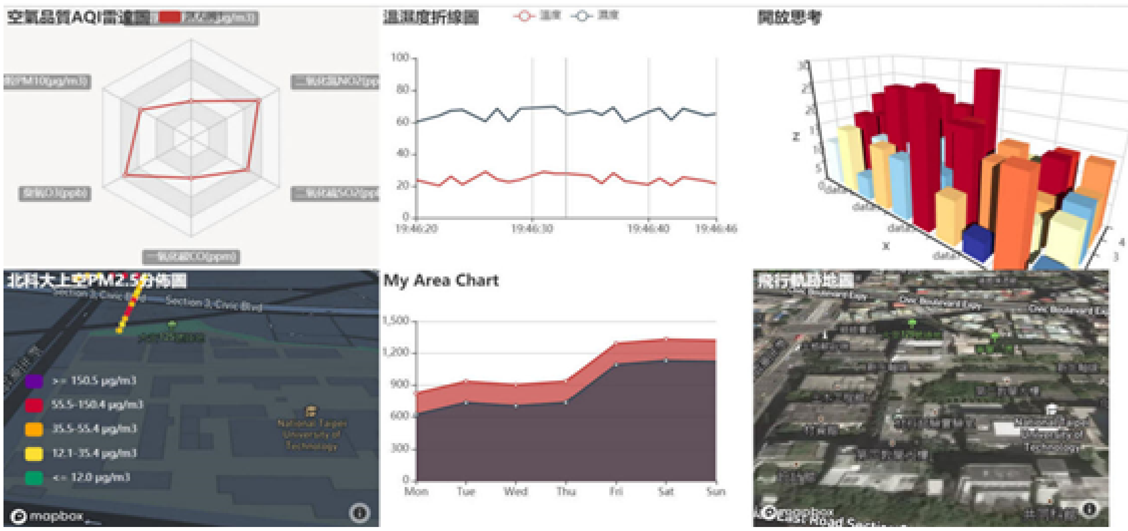

Fig. 1. Information Visualization Module Dashboard (From Left to Right, From Top to Bottom, Air Quality (AQI) Radar Chart, Temperature, and Humidity Line Chart, 3D Histogram, NTUT PM2.5 Distribution Chart, My Area Chart, UVA Flight Path Diagram)

TABLE 1
INTERACTIVE SMART SPACE DESIGN COURSE

Week	Course Syllabus	Course Content
1-2	Introduction to Project, Python Basics, JSON, and Cloud Repositories	Introduce Project development environment installation, Project program architecture, Python, JSON data exchange format, cloud database Firebase, etc.
3-5	JavaScript basics, process control, and advanced	Introduce the basics of JavaScript, including variables and operands, JavaScript flow control, logical judgment, loops, and exception handling, and advanced JavaScript, including arrays and functions.
6-7	Echarts introduction and example explanation	Introduce the features and usage of the Echarts visualization suite, start from scratch, and explain the project code.
8	Interface design cases and phased results sharing	The teacher introduced the interface design case, and the students reported the staged results and grading discussions in teams.
9-10	Information Visualization, Interface Design Thinking, and Evaluation	Ergo, cognition and gestalt, information visualization, interface usability and usefulness, and smooth experience.
11-12	Space design and dynamic system interface integration	Introduce spatial positioning and navigation book search system, UVA smart campus, smart city, and dynamic information visualization integration, application, and design.
13	Use situational simulation learning and staged results sharing	The teacher introduces situational simulations, and students report staged results and graded team discussions.
14-15	Multi-UAV cloud control interface design and UAV program development	Introduce how to use JavaScript and the Internet to control multiple drones simultaneously, display the status and position of the drones in real time, and plan the flight path. Use Python to control drones and process drone streaming images.
16	Multi-person drone dashboard and staged results sharing	The teacher introduced the multi-person drone dashboard, and the students reported the final results and graded discussions in teams.

ISSN: 2414-4592
DOI: 10.20474/jater-8.1.3

TABLE 2
THEMATIC REPORTS FOR EACH TEAM

No	First Team	Second Team	Third Team
Theme	Smart fish breeding ponds	Health Environment Detection	Campus Epidemic Prevention
Theme Core	Fly into the fish pond through the UAV hanging sensor to measure the water quality data. It is hoped that through the data hole of the relevant water quality sensor, the abnormality in the water can be detected early, and the disaster loss can be reduced.	With the advancement of science and technology, harmful substances in the air have increased, especially radioactive ones. UAV provides a regional detection service, mainly measuring radiation concentration and air quality.	Cruise on a fixed route with the UAV; any mode will display the location and route on the map. The heat map shows the school's control of the flow of people during the epidemic prevention period. The darker the red, the more dangerous the population, and the darker the blue, the safer, the fewer the number of people.
Information Visualization	Chart: Water pH, Dissolved Oxygen and Temperature, O.R.P. Redox Operation interface: UAV path RWD Web map	Chart: Ultraviolet Detection, Radiation Detection, Air Quality Detection Operation interface: UAV path 2D map	Chart: Average temperature detection, number of people detection Operation interface: UAV cruise route map, regional flow heat map
Program	• MySQL • Github • Chart.js • RWD Web	• Python Simulator • Apache Echarts • Mapbox	• Simulator • Apache Echarts • RWD Web

III. RESULT & DISCUSSION

The purpose of this research is to guide interdisciplinary students in collaborative learning through programming and visualization through the application of modular programming and information visualization with the theme of intelligent city space through the interdisciplinary course of "Interactive Smart Space Design" and develop the use of Interactive intelligent interface between users and environmental data.

From the research results, it can be found that in the expert evaluation and advice, such as Table 3, in the topic formulation, among the three teams of students, two teams changed the topic in the middle. In the application and development of programs, in addition to technical problems, the common problem lies in the feasibility evaluation of the actual execution of the program. In addition, there are also two teams of data storage problems. In infographics, the common problem is that experts suggest that the appropriate graphs should be presented for the topic. The data and graphs should provide clear text descriptions and must have their meanings. The team division mode and effective communication are common problems in evaluating collaborative learning. In the overall problem convergence, experts believe that the biggest problems in each team lack the description of the theme and the description of the use situation and should be perfect for the source and meaning of information. Finally, we also put forward revision strategies and suggestions for each team, use the situational simulation for themes, are good at using storytelling to describe the user's plot in depth, strengthen time management on projects, and technically suggest that models can be constructed or version kits can be used to enhance information vision.

In team collaboration and self-assessment, such as Table 4, on the advantages and disadvantages of collaborative learning, students think it is a good arrangement for people with different professional abilities to be in the same team. Participation and communication in meetings also have an impact on collaborative learning. As for project development problems, students think the biggest problem is still in program development, including unfamiliarity with Echarts software, data simulation/collection/meaning, version control, and unfamiliar equipment. The three teams of students have the same consensus on strengthening project collaboration, including searching for information on the Internet, examples or referring to previous students' examples, the use of infographics and data presentation, and the implementation of similar enterprise project management models (such as Team member communication efficiency and methods/project management/time management). Fi-

ISSN: 2414-4592
DOI: 10.20474/jater-8.1.3

nally, the self-evaluation that needs to be strengthened is establishing a more active work distribution method in cooperation. In development, it is hoped that subordinate projects will be deployed to the cloud server to train their prediction models and try to record big data, simplify the design of charts, and strengthen UI/UX to improve the use and user experience.

Comparing the viewpoints of expert evaluation and students' self-evaluation, the following points can be found: The three teams of students all lack the description of the theme, and the use situation or the theme is unclear in the evaluation. The common factor is the lack of the ability to tell stories and design marketing for the theme, and the cause is also related to the composition of the team members as students with design and engineering backgrounds. In the related interdisciplinary study courses, it is possible to consider adding students with backgrounds related to humanities, sciences, and culture to increase the diversity of topics and contents. The change of themes, unfamiliarity with the expertise of the team members, unclear division of labour, and time management are caused mainly by the lack of effective communication in the team and the lack of experience in project management. Although there are many coordination and corrections in the process, the students are running with each other and accumulating experience growth. Finally, in terms of cross-domain learning performance, modular programming and information visualization charts are integrated and applied, and the simulation results of the theme are still presented with a high degree of integrity, such as in Fig. 2-4.

TABLE 3
EXPERT ASSESSMENT AND ADVICE

No	First Team	Second Team	Third Team
Theme Shift	Smart fish breeding ponds (Keep)	Radiation Detection(Shift) Health Environment Detection (final)	Weather Forecast (Shift) Campus Epidemic Prevention (final)
Program application development	• The difficult part of the program implementation can still be used to present the concept with pictures • Enhanced storage of multiple data • Program version control • The sensor range is limited • Echarts replace Chart.js • Firebase replaces MySQL	Radiation detection: • U.V. record • Echarts modification Health and Environmental Testing: • Provide technical feasibility and requirements • A large amount of data per second consumes traffic • Assess the real feasibility	Weather forecast: • The program needs to be strengthened Campus Epidemic Prevention: • LSTM predicted weather values • Technical feasibility assessment • Good concept but lacks actual representation of code • Web pages use JavaScript • Assess the real feasibility
Use of in-fographics	• The relationship between dissolved oxygen and average temperature • Dissolved oxygen map and temperature map • Redox diagram • The coordinates of the map/overall map • Line chart • UAV interface can be further enhanced • UAV marking (colour/number) • Visual warning effects can appear • RWD-Mobile Version (Fisherman)	Radiation detection: • No map application • Choose the appropriate chart (beautiful level) • Web page layout beautification Health and Environmental Testing: • Provide technical feasibility and requirements • A large amount of data per second consumes traffic • Assess the real feasibility	Weather forecast: • UI/UX needs to be strengthened Campus Epidemic Prevention: • People flow grid heat map • Grid heatmap (people flow?) • Mask monitoring (map?) • Icon has not only colour but also size • The entire dashboard design • We need to add a date and time display • Relationship of graphs (data information)
Collaborative Learning Assessment	• Team division and cooperation • Team communication Time invested by team members • Integrated communication is not good enough • Each position and work style • Cross-domain division of labour • Strengthen cooperation and tacit understanding	• Friendly communication • Some team members do not actively participate • The division of labour is not clear enough	• Online PPT discussion • The theme begins to be clear • Clear division of labour

ISSN: 2414-4592
DOI: 10.20474/jater-8.1.3

TABLE 3 CONTINUE....

No	First Team	Second Team	Third Team
Overall problem convergence	• Lack of topic description and usage context • Solutions to uneven distribution of water quality • UAV dynamic - fish centre chasing dynamic • Poor visualization of information needs to be strengthened • fish breeding ponds - meaning of visualization	Radiation detection: • Lack of topic description and usage context • Rendering charts are not clear Health and Environmental Testing: • Are those values of high pollution meaningful? • Who are the target customers? What are the needs of the owners? • The application limit should be clarified in the field that can be further penetrated • Air mass boundary problem • Hazardous area definition?	Weather forecast: • The topic is not clear Campus Epidemic Prevention: • The building can not see the flow of people • Overall UI? • Body temperature detection • Body temperature monitoring Crowd monitoring • Thinking about the image recognition system • What is the source of information about the flow of people? • Technical practice? (person I.D., body temperature) infrared measurement?
Modification strategies and recommendations	• Look at other people's cases/combined with real cases • Model building • Should be good at telling a story • Cross-domain (Imagination/ UI/UX) • Available version kits • Strengthen time management • Strengthen information visualization	Radiation detection: • Add map • Strengthen time management • Strengthen information visualization • Strengthen user context Health and Environmental Testing: • Health Information (E.C.G./Smart Watch) • Comparison of environmental advantages and disadvantages • Use situational simulation • Remote monitoring • The application is feasible and can be thought deeply for specific scenarios • External knowledge introduction (field/function) • Thinking about problems can be combined with geography	Weather forecast: • Weather data model construction/measurement • (airbox/balloon/UAV high-altitude data/climate fixed point) Campus Epidemic Prevention: • UAV high-altitude computing people flow-visualization-spatial architecture-spatial syntax • The story narrative is straightforward and can be further deepened • UAVs detect masks and body temperature • Patrol - static (specific point)/dynamic (cruise) - certain path/emergency • There is a full-story narrative

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TABLE 4
TEAM COLLABORATION AND SELF-ASSESSMENT

No	First Team	Second Team	Third Team
Advantages and short-coming of collaborative learning	advantage • Team members have experience with coding implementation and presentation skills shortcoming • Unfamiliar with their respective expertise • Meeting attendance problems • Project management issues	advantage • Friendly communication shortcoming • Fewer meetings • Time (progress) allocation is not perfect • The division of labour is not clear	advantage • Good visual optimization ability • Team members are willing to communicate • The team members have good programming skills shortcoming • The division of labour can be more clearly defined • There are errors in team text communication
Problems with project development	• The package dependency problem prevents the old and new functions from being mixed • Unfamiliar with specific software and not good at using it • Unfamiliar with the meaning behind the values of each sensor • Modular programming example writing is too difficult • Modular programming has built-in git version control, causing synchronization problems • Need to understand code writing specifications	• Not familiar with Echarts • Database system maintenance • The equipment is difficult to operate	• It is not clear what data drones can collect • No one has experience with Echarts • The simulation of the data is difficult to set
Enhanced project collaboration	• Understand the meaning behind the values of each sensor, • Increase the number of meetings and discussions • Need for better time management • Use better project management to ensure project progress and improve overall development efficiency • Make good use of online discussion tools • Study Echarts charts • Use of information visualization charts	• An online search for information and examples • Actively communicate in groups • Choose the appropriate chart to present the data	• Find various information on the Internet • Projects completed by previous students as a reference • Change the way of communication to improve the communication efficiency of team members
To be strengthened in the future	• Improve user experience • Enhanced UI/UX • Deploy the project to the cloud server • Create a more proactive approach to work distribution	• UAV endurance problem • A large number of data records that are updated frequently are difficult to update	• Referring to the industry divide labour by profession • Find relevant historical data as much as possible and train its predictive model • Diagram design to simplify integration

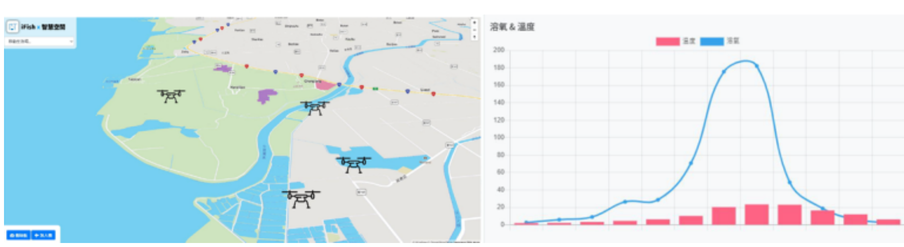

Fig. 2. Smart Fish Breeding Ponds (First Team)

ISSN: 2414-4592
DOI: 10.20474/jater-8.1.3

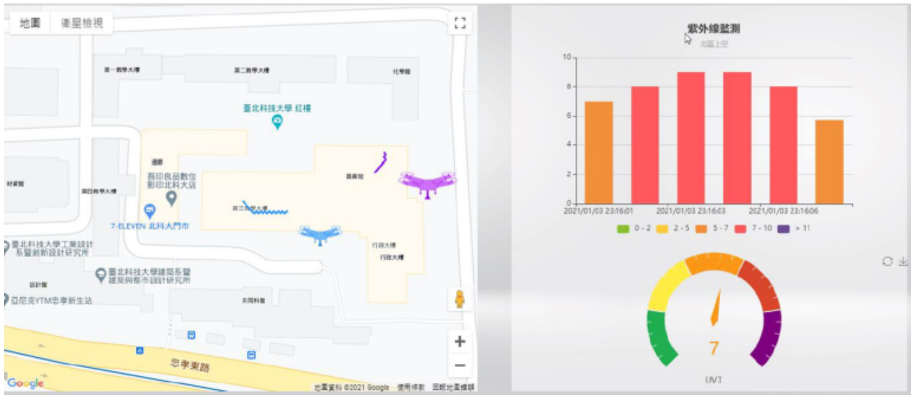

Fig. 3. Health and Environmental Testing (Second Team)

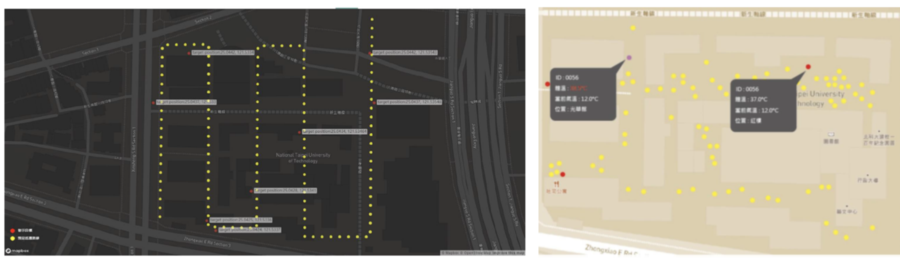
Fig. 4. Campus Epidemic Prevention (Third Team)

IV. CONCLUSION

In this research, we teach students in different fields to collaborate on the division of labour through an interdisciplinary course with the theme of creative city space. The course decomposes problems, establishes models, applies modular programming, and establishes visual interface charts with corresponding mechanisms. Indirectly train students to integrate computational thinking and design thinking with projects and learn coordination and experience of group collaboration in the process, and the results show the effectiveness of learning. In the follow-up research, further data collection and simulation prediction verification will be carried out through UAVs, and the similarities and differences will be discussed. With more objective and credible environmental data and its factors, it provides a reference basis for developing smart cities.

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