Article

Development and Evaluation of Fishbone-Based Advanced Computational Thinking (FACT) Pedagogy: A Teacher-Student Collaborative Learning Environment in Engineering and Science Education

Higher Education for the Future
8(1) 108–122, 2021

DOI: 10.1177/2347631120970177
journals.sagepub.com/home/hef
SAGE

B. Gopinath[1] and R. Santhi[2]

Abstract

In this article, Fishbone-based advanced computational thinking (FACT) pedagogy is proposed by fusing fishbone pedagogy and computational thinking pedagogy for enhancing teaching-learning process while teaching engineering and science courses, for engineering and science students respectively. The proposed FACT pedagogy has been implemented using the concept of X-ray machine in biomedical instrumentation course and biomolecules, in biochemistry course. Using fishbone approach, various components of X-ray machine in biomedical course and the components of biomolecules in biochemistry course are visually explained as ribs and riblets of a fishbone diagram, without coining the keywords X-ray and biomolecules in an engineering institution and science institution respectively. Finally, the targeted concept is arrived and explained. Similarly, the same concepts of X-ray and biomolecules are coined among students and they are asked to divide or decompose the concepts into sub-concepts separately. To implement and evaluate the proposed pedagogy, an engineering institution and a science institution have been selected and evaluation results have been published in this

[1] Department of Electronics and Communication Engineering, Kumaraguru College of Technology, Coimbatore, Tamil Nadu, India.
[2] Department of Biochemistry, PSG College of Arts & Science, Coimbatore, Tamil Nadu, India.

Corresponding author:
B. Gopinath, Associate Professor, Department of Electronics and Communication Engineering, Kumaraguru College of Technology, Coimbatore, Tamil Nadu 641049, India.
E-mail: gopinath.b.ece@kct.ac.in

article. In this pedagogical approach, the same complex concept is taught as a backward thinking by the teacher using fishbone pedagogy and forward thinking by the students using computational thinking pedagogy. This combined approach helps students to understand any complex concept in science courses. Also, it helps the teachers to easily convey and embed the same among the student community while teaching science courses.

Keywords

Biomolecules, computational thinking, FACT, fishbone, teaching-learning

Introduction

Teaching a science course in a classroom to a group of students is a challenging task. To easily transfer scientific knowledge to students, various pedagogies are being used by the teaching community such as basic lecture mode, power point presentation, word games, fishbone diagram, flipped classroom, role play, storytelling, computational thinking, science fair, video clips, science games and movies, science quiz, science clubs, field trips, and so on. Though there are numerous proved pedagogies, new pedagogical approaches are being invented and tested by the teaching community. In this sequence, a new pedagogy in the name of fishbone-based advanced computational thinking (FACT) pedagogy is proposed by fusing two well-known pedagogies, namely fishbone pedagogy and computational thinking pedagogy. A fishbone diagram based pedagogy helps students to visually understand a problem with its root causes and encourages them to solve the problem (Slameto, 2016; Prasad, 2012). On the other hand, the computational thinking is an advanced pedagogy to improve the problem-solving skills of students by decomposing large problems into small units (Hoyles & Noss, 2015).

Fishbone Diagram Pedagogy

A fishbone diagram or cause and effect diagram, or the Ishikawa diagram was developed by Dr. Kaoru Ishikawa in University of Tokyo in the year 1943. It is used by the teaching community as a visual pedagogical methodology through which various root causes of a problem can be summarized. In this fish shaped diagram, the head of the fish represents the problem or concept, the ribs show the root causes and riblets show the relationship between the causes. The concept of fishbone diagram is a widely applied pedagogy in teaching-learning process (Bryk et al., 2015).

The critical thinking ability of students was evaluated (Istikomah, 2017) with various problem-based learning models, namely fishbone diagram, problem-based learning model and expository learning model. The findings have observed a significant difference in critical thinking ability of students and the problem-based learning was acting as a secondary learning approach to improve the critical thinking ability of students. Sufeni and Fatimah (2018) tested the teaching of writing discussion text using fishbone diagram among the senior high school students and promising outcomes were obtained. As a teaching tool, the effectiveness of fishbone diagram was evaluated among nursing students of a nursing college and it was found that the fishbone diagram was an effective tool for laboratory investigations to create promising strategies in nursing education (Latha & Merlin, 2019).

The role of self-education and self-study methods were dealt using fishbone technology implementation (Viktorovna & Viktorovna, 2020). The study concluded that this methodology established a causal relationship between the objects under the study and the factors influencing in educational activities. This process was implemented in understanding of industrial technology targeting vocational category of university students. The active keywords namely, event analysis, fishbone structures and socionist analysis were discussed which were used to develop the critical thinking of students (Kovpik, 2020). To observe the supervision practises and review student teaching observation and evaluation protocols, a team (Sullivan et al., 2020) conducted a brainstorm using fishbone concept and a fishbone diagram was generated which helped to arrive a problem statement. A typical structure of a fishbone diagram is shown in Figure 1.

The following steps are required to draw a fishbone diagram for teaching a problem or concept to a group of students in a classroom.

Step 1: A flip chart or a black/white board is used to draw the fishbone diagram.
Step 2: A complex problem or concept is taken to solve or explain and written on the right side of the board/chart which is treated as the head of a fish.
Step 3: From the head, a straight horizontal line is drawn from right to left direction which is treated as the backbone of the fish.

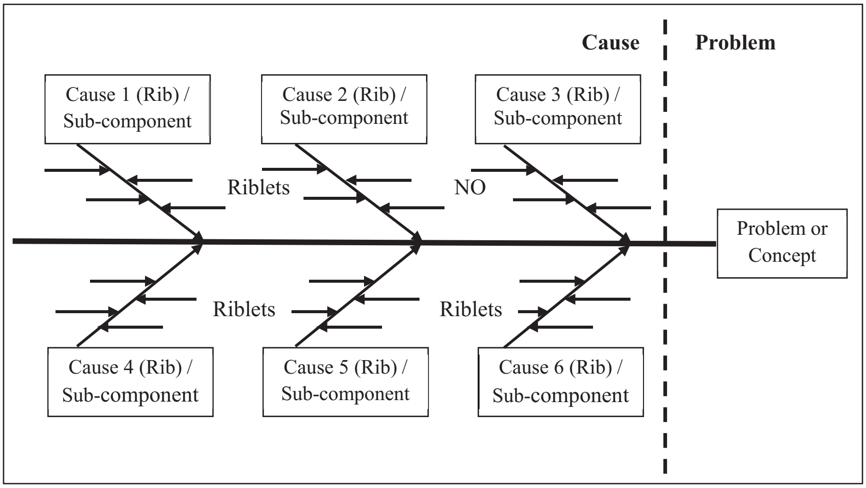

Figure 1. A Typical Structure of Fishbone Diagram.

Source: The authors.

Step 4: Now, the causes of the targeted problem or sub-components of the concept are identified and added to the backbone as rectangular boxes which are treated as ribs of the fish. With each rib, short horizontal lines with arrow heads are attached to explain the relationship between the causes which are treated as riblets. The causes may be identified by the teacher or by conducting a brainstorming session.

Step 5: In a non-conventional manner, teachers may start the diagram from ribs of the fish rather than head of the fish. This practise is used to explain about a set of causes which will lead to a problem or a set of sub-components which will help to understand a concept. To implement the Step 6, the order of the above steps should be rearranged as Step 1, Step 4, Step 3 and Step 2 respectively.

Computational Thinking (CT) Pedagogy

The concept of computational thinking pedagogy was first coined by Papert (1996), who is known for the development of the Logo software. Qin (2009) analyzed the teaching of computational thinking through bioinformatics for biology students. Barr and Stephenson (2011) presented a framework for building computational thinking skills. They concluded that this framework can enhance the understanding of the subjects such as computer science, mathematics, science, social studies and language arts. Hoyles and Noss (2015) approached the computational thinking for seeing a problem at different levels of detail (abstraction), as a task in terms of smaller connected discrete steps (algorithmic thinking), solving a problem that involves solving a set of smaller problems (decomposition) and pattern recognition. These components are mainly used by the computer science experts to demonstrate the fundamental concepts of computing. However, it is nowadays used by all the teaching community for teaching various fields of interest (Zuena, 2018). Pérez (2018) developed a collaborative framework to integrate the concepts of computational thinking pedagogy in mathematics learning. The study revealed that the CT is not only suitable for teaching computer education but also suitable for mathematics learnings.

A latest study conducted by Kong et al. (2020) demonstrated the significant nature of offering an effective teacher development programme using computation thinking approach. For the targeted study, the design and evaluation were implemented on 76 primary school teachers. The teachers were permitted to practise and perform in the classroom while developing their capacity to implement CT in relation to programming. A study was conducted by Ketelhut et al. (2020) on computer science education to develop involvement of students and basic understandings of the students. The study focused on elementary teachers to teach computer science using computational thinking by integrating CT into science education. The growing nature of computational thinking in science, technology, engineering and mathematics (STEM) was reviewed (Lyon &

Magana, 2020). Based on various parameters such as types of methods, target population and the role of computational thinking, a set of 13 studies were reviewed and the results showed that there are huge opportunities for CT research in higher education. A model of computational thinking pedagogical content knowledge (CTPCK) was reviewed (Gaul & Kim, 2020) as a teacher-centric approach. Based on the results, it was identified that the CTPCK framework might be used to identify gaps in understanding level of teachers and guide them towards the professional development.

Computational thinking improves the immense potential in nurturing students' problem-solving skills which are highly needed under the technology era. In Malaysia, various steps have been taken to develop and implement strong computational thinking among school students which are being used to solve complex problems (Saad, 2020). The integration of education faculty and computer science faculty was executed in an experimental way for five educational technology classes in a university in the southern United States with a total of 88 undergraduate and graduate students (Powers & Azhar, 2020). The responses of students and the future directions were studied for integrating CT into teacher education curricula. Based on the literature review, the computational thinking can be realized as any one of the four components as shown in Figure 2 that consists of:

- Decomposition (analyzing and solving a problem by breaking it into smaller parts)
- Pattern recognition (finding patterns, sequences and regularities in a given data set)
- Abstraction (observing or viewing a problem at different levels of detail)
- Algorithm design (developing step-by-step instructions for solving a problem)

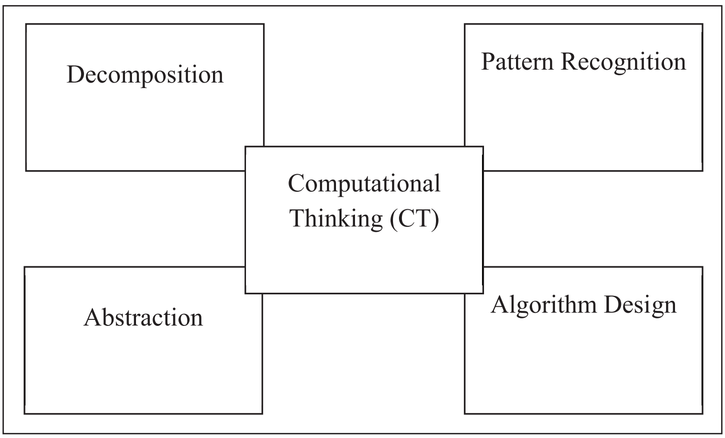

Figure 2. Realization of Computational Thinking.

Source: The authors.

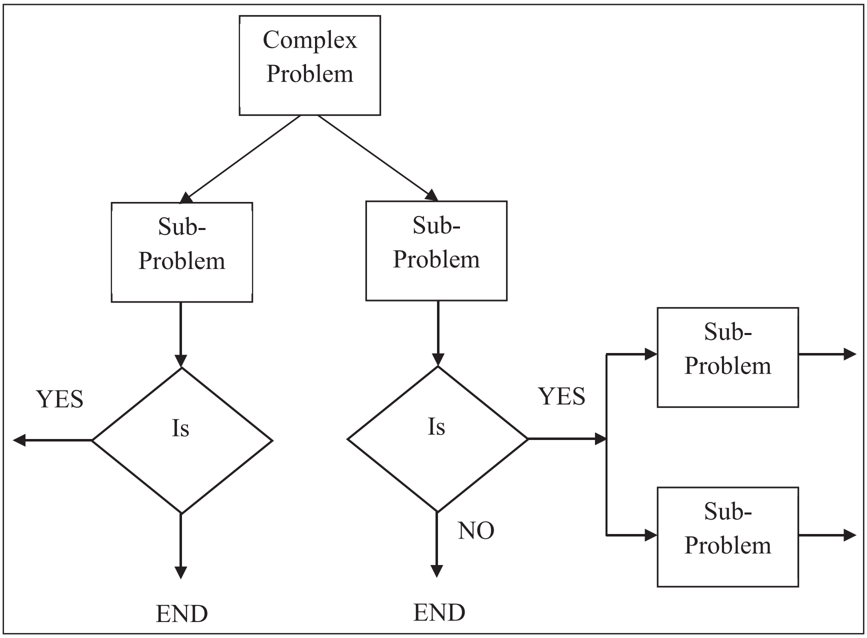

Figure 3. Representation of Computational Thinking as Decomposition Process.
Source: The authors.

For the proposed pedagogy, the CT pedagogy is used as the decomposition process. In the decomposition based CT pedagogy, the given complex problem is decomposed into smaller sub-problems as shown in Figure 3. If any one of the smaller sub-problem is still complex, then the complex sub-problem is decomposed into further smaller sub-problem. Now, the sub-problems are solved to get the appropriate solutions and these solutions are combined to get a final solution for the given complex problem.

The Proposed FACT Pedagogy

In this article, fishbone-based advanced computational thinking (FACT) pedagogy is proposed as a fusion of two pedagogies namely, fishbone pedagogy and CT pedagogy. The salient features of both the pedagogies are selected and combined to develop the FACT pedagogy. The conventional keywords used in both the pedagogies are mapped into alternate keywords in the proposed FACT pedagogy as listed in Table 1.

Table 1. Analogy Keywords Between Fishbone, Computational Thinking and FACT Pedagogies

Name of the pedagogy	Keyword(s)	Modified Keyword(s) in FACT
Fishbone	Problem (Head)	Concept
	Cause (Rib)	Sub-concept
	Relationship between causes (Riblets)	Relationship between Sub-concepts
Computation thinking	Problem	Concept
	Decomposition	Division
	Small problems	Sub-concepts

Source: The authors.

In FACT pedagogy, the fishbone approach is used to explain a concept in reverse direction by the teacher from sub-concept to concept whereas the CT approach is used to explain the same concept in forward direction by students from concept to sub-concept. A concept which is to be delivered to students is explained using a set of sub-concepts by the teacher without coining the name of the concept using fishbone pedagogy as a reverse approach. At the end of the content delivery, the teacher can make the students arrive to and understand the name of the targeted concept. On the other hand, as a forward approach, the name of the concept is initially declared, and students are asked to decompose the main concept into sub-concepts in accordance with CT pedagogy. Since the same concept is dealt twice in backward and forward manner, an enhanced teaching-learning can be realized using the proposed pedagogy.

The following steps can be executed to implement the proposed FACT pedagogy for teaching a concept to a group of students in the classroom.

Step 1: A black/white board is used to draw the fishbone diagram.

Step 2: A complex concept which is to be delivered to students is taken but the name of the concept is not revealed to students. The known sub-concept(s), which are treated as the ribs a fish, are written on the left side of the board and explained.

Step 3: With each sub-concept(s), short horizontal lines with arrow heads (riblets) are attached to explain the relationship between the sub-concepts.

Step 4: By connecting all the ribs, a straight horizontal line is drawn from left to right direction which is treated as the backbone of the fish and ended with head of the fish or unknown concept as shown in Figure 4. Thus, the unknown concept is arrived through known sub-concepts. At this step, the role of fishbone diagram is ended.

Step 5: From this step onwards, the CT pedagogy is started. In this step, the same complex concept is initially coined to students and they are asked to divide or decompose it into sub-concepts.

Step 6: A tree structure to indicate the decomposition or division of concept into sub-concepts is drawn by students, as shown in Figure 4, which connects the main concept and all other sub-concepts.

Step 7: Finally, a concluding session is conducted to narrate the overall content from sub-concepts to concept in backward direction and concept to sub-concepts in forward direction.

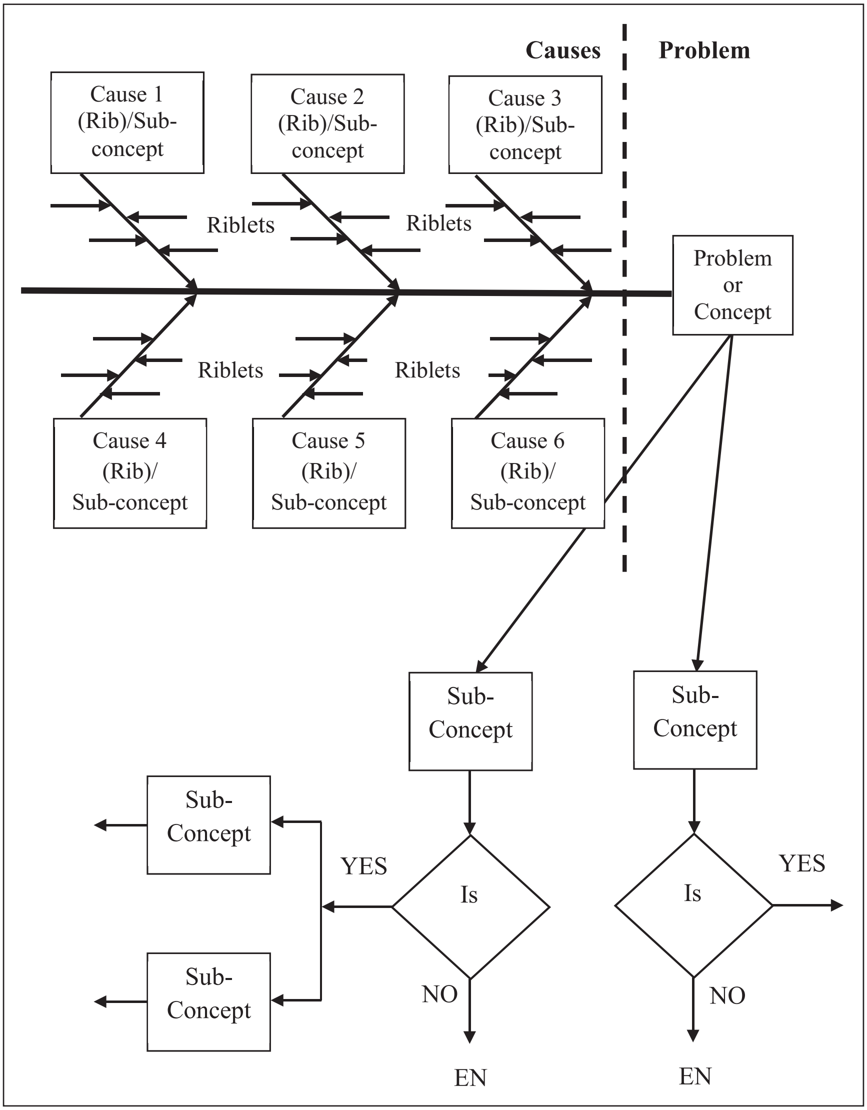

Figure 4. The Proposed FACT Pedagogy.

Source: The authors.

Implementation of the Proposed FACT Pedagogy in Engineering Institution

The proposed FACT pedagogy can be implemented to explain any complex concept in engineering courses. For illustration purpose, the concept of X-ray machine has been taken from biomedical engineering course and explained targeting a batch of 42 students. An X-ray machine is used as an imaging equipment to view the inside of patient's body to diagnose abnormal conditions such as tooth decay, bone cancer, fractures, and so on using radiology techniques. The X-ray machine consists of X-ray tube (collimators, focusing cathode and Tungsten anode), transformer (autotransformer, step-down transformer and high-tension transformer), control unit (current control, voltage control and time control) and other parts (protective housing, patient table and radiographic film).

In accordance with the proposed FACT pedagogy, the concept of X-ray is taught first by using fishbone diagram without coining the term X-ray. Instead of that, the four sub-concepts namely, X-ray tube, transformer, control unit and other parts are taught by drawing a fishbone diagram as shown in Figure 5.

The components of X-ray machine and the operation of the machine is then explained sequentially. The X-ray tube is an electrical device that consists of a cathode and an anode. When the electrical current flows from cathode to anode, the electrons result in the generation of X-ray radiation using a suitable mechanism. The cathode emits the electrons inside the tube and focuses them at the anode. Similarly, the anode is used to convert electric energy into X-ray radiation. Another component, Collimator, is used to regulate the X-ray radiation dose between the cathode and the anode. The control unit controls the three parameters—voltage, current and time. The voltage applied to the X-ray tube, the electric current flowing through the tube and the duration of the exposure are controlled by the control unit.

The transformer section consists of three types of transformers—autotransformer, step-down transformer and high-tension transformer. The autotransformer permits some fluctuations in the line voltage to be tuned at a required point before the current is supplied to the high-tension transformer. The step-down transformer allows the supply to reach a reduced current at the cathode. Now, the high-tension transformer produces the required high voltage for the generation of X- rays. The entire X-ray mechanism is surrounded by a well packed, thick lead shield housing that stops the scattering of X-rays in all directions. Another function of the housing is to cool the X-ray tube. The films are used to store the final imaging of the patient's internal target part. During the interaction of the X-ray with film, it causes electro-chemical changes in the film which will create blackness. Finally, the X-ray table is an important part which is for the patient's usage. It is available under three categories—stationary, mobile and floating models in accordance with different applications.

At the end of the Fishbone diagram, head of the fish is drawn and the name of the concept is revealed as 'X-ray machine' in reverse order. The ribs or sub-concepts of X-ray tube, transformer, control unit and other parts are forming the main concept of X-ray machine. Now, the concept of X-ray machine is given to students and they are asked to divide or decompose the concept into sub-concepts in forward direction using computational thinking pedagogy. If the sub-concept is complex, it is divided into further sub-concepts. In X-ray machine, the sub-concept 'other parts' is treated as complex and divided into film and housing as shown in Figure 5. This methodology can kindle the thinking and understanding power of students.

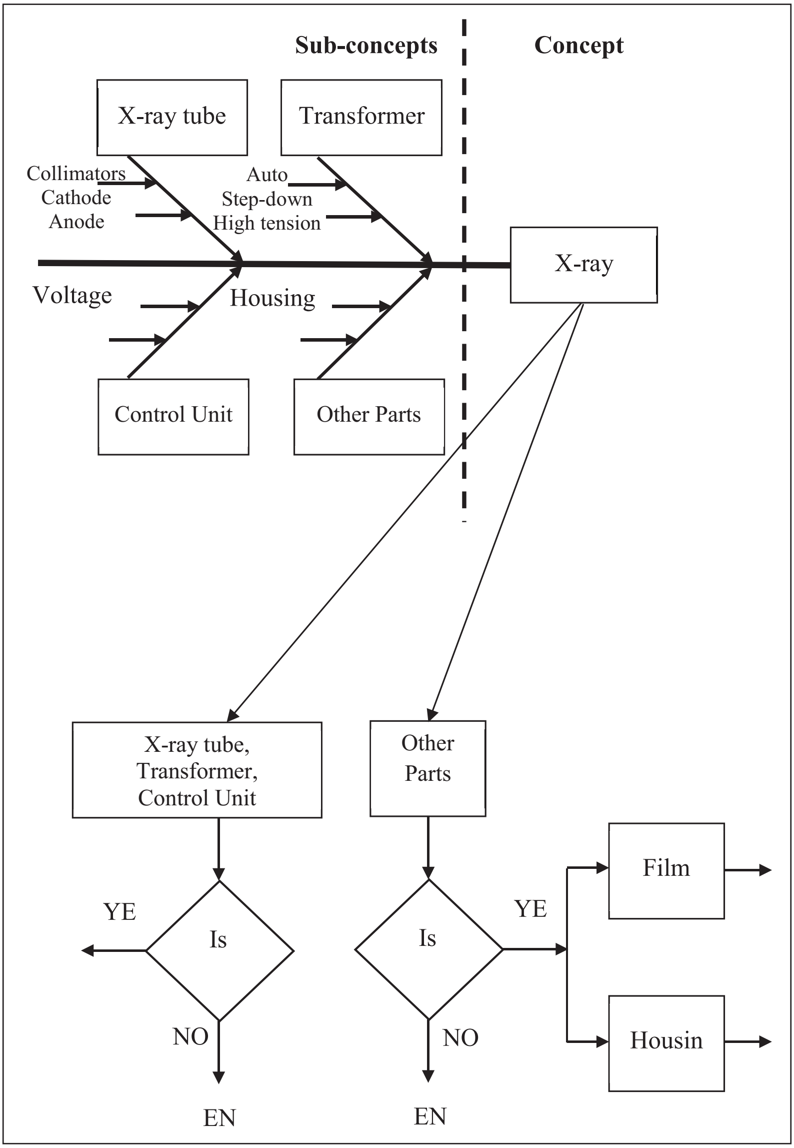

Figure 5. Illustration of the Proposed FACT Pedagogy Using X-ray Concept.

Source: The authors.

Implementation of the Proposed FACT Pedagogy in Science Institution

The proposed FACT pedagogy can be implemented to explain any complex concept in science courses. For illustration purpose, the concept of biomolecules has been taken from biochemistry course and explained targeting a batch of 48 students. Cell is a fundamental unit of life and store house of biomolecules which are responsible for the various bioactions. Biomolecules consist of thousands of atoms assembled by linking hundreds of smaller molecules into long chains. There are four types of biomolecules—carbohydrates, lipids, proteins and nucleic

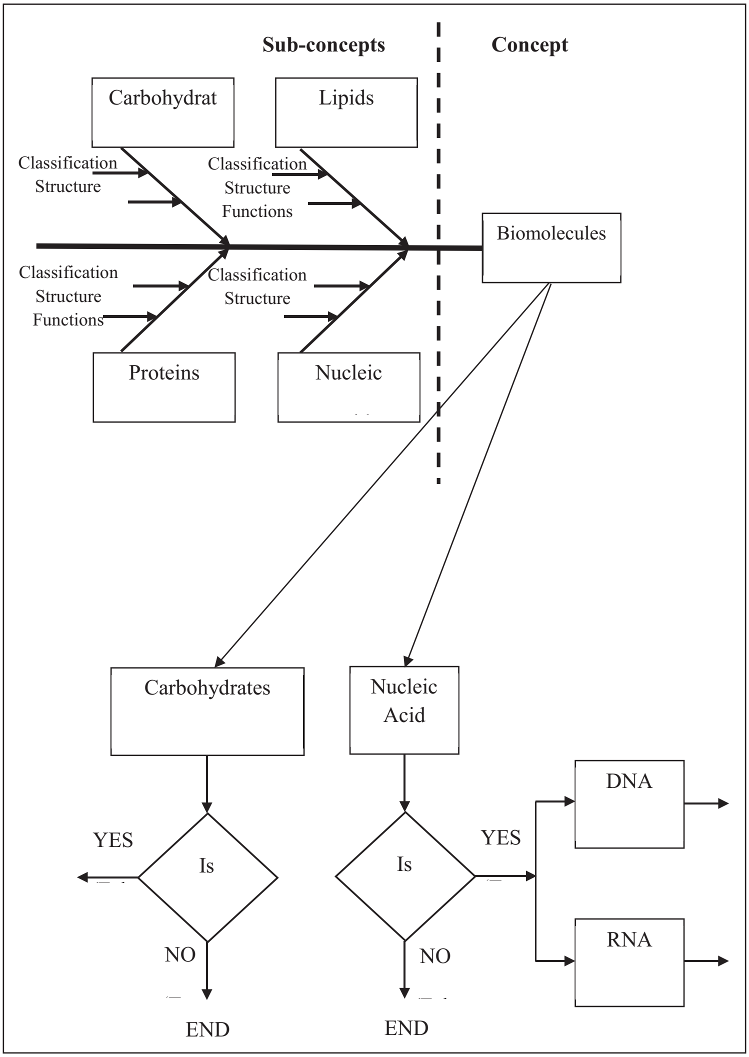

Figure 6. Illustration of the Proposed FACT Pedagogy Using Biomolecules Concept.

Source: The authors.

acids. In accordance with the proposed FACT pedagogy, the concept of biomolecules is taught first by using fishbone diagram without coining the term biomolecules. Instead, the four sub-concepts—carbohydrates, lipids, proteins and nucleic acids—are taught by drawing a fishbone diagram as shown in Figure 6.

Carbohydrates are polyhydroxy aldehydes or ketones and their derivatives that yield one of these compounds on hydrolysis. Sugars are simple carbohydrates that function as energy storage molecules as well as structural elements. It contains carbon, hydrogen and oxygen in the ratio of 1:2:1. It contains many carbon-hydrogen bonds which releases energy when broken and is well-suited for energy storage. The carbohydrates are used in one of three ways:

1. maintained as glucose and is available for immediate energy
2. converted into transport disaccharides and carried to other parts of the organism
3. converted into storage forms, such as fats, and reserved for future use

Protein is composed of one or more polypeptide chains possessing a characteristic amino acid sequence. It is a polymer of amino acids and an essential constituent of living cells. It makes up 12 per cent of the protoplasm. They are body builders. They contain carbon, nitrogen, hydrogen, oxygen and sometimes sulphur. They are constructed largely of amino acids. Lipids are a heterogeneous group of compounds related to fatty acids. They are the esters of alcohol and fatty acids. They are composed of three fatty acids joined to an alcohol. Saturated fatty acid contains the maximum number of hydrogen atoms and no double bonds. Unsaturated fatty acid contains one or more double bonds between successive carbon atoms. Nucleic acids are the information storage centres of the cells. There are two types of nucleic acids—DNA (deoxyribonucleic acid) and RNA (ribonucleic acid). Long polymers of repeating subunits are called nucleotides that consist of a five-carbon ribose or deoxyribose sugar, a phosphate group and an organic, nitrogen-containing base. Nucleic acid polymers are formed when the phosphate group of one nucleotide binds to the hydroxyl group of another and form a phosphodiester bond.

At the end of the fishbone diagram, the head of the fish is drawn and the name of the concept is revealed as 'Biomolecules' in reverse order. The carbohydrates, lipids, proteins and nucleic acids are declared as ribs or sub-concepts of the Biomolecules. Now, the concept of biomolecules is given to students and they are asked to divide or decompose the concept into sub-concepts in forward direction using computational thinking pedagogy. If the sub-concept is complex, it is divided into further sub-concepts. In biomolecules, the sub-concept Nucleic acids is treated as complex and divided into DNA and RNA as shown in Figure 6. This methodology can kindle the thinking and understanding power of students.

Evaluation of the Proposed FACT Pedagogy

As narrated in the previous sections, the proposed FACT pedagogy was taught in both engineering institution and science institution using the appropriate

Table 2. Summary of Evaluation Results of FACT Pedagogy

Total number students participated		Evaluation results as marks (%)							
		Range of marks in Engineering stream				Range of marks in Science stream			
Engineering stream	Science stream	91–100 (A)	81–90 (B)	71–80 (C)	51–70 (D)	91–100 (A)	81–90 (B)	71–80 (C)	51–70 (D)
42	48	66	19	10	5	63	23	11	3

Source: The authors.

topics from engineering and science courses respectively. For the purpose of the evaluation of the proposed pedagogy, a set of questionnaires are prepared and supplied to students at the end of delivery in the classroom. The questionnaires consisted of 15 multiple choice questions on a single side of A4 sheet. All the questions were from the topics taught using the FACT pedagogy. A time limit of 10 minutes was allotted to answer the questions and the answer papers were evaluated at the end of the class. The evaluation results have been summarized in Table 2.

The evaluation of the proposed FACT pedagogy was carried out in terms of marks obtained by the students of engineering stream and science stream. Their understanding levels are categorized into four grades from A to D. From Table 2, it is evident that less number of students scored, that is, 5 per cent and 3 per cent of students in engineering and science streams respectively obtained the grade D. Remaining set of students obtained a reasonable grades of A, B and C in both engineering and science streams. It shows that the proposed FACT pedagogy performs well in conveying the complex concepts in students of both engineering and science streams. It has also been proved that the proposed pedagogy has enhanced the understanding calibre of student community.

Conclusion

As a cascade approach of two well-known pedagogies, the fishbone-based advanced computational thinking (FACT) pedagogy was proposed for easy understanding of complex engineering and science concepts for enhancing the teaching-learning process. In this combined pedagogical methodology, the root causes represented by the ribs of fish diagram were mapped into their corresponding sub-concepts in computational thinking pedagogy. The concepts of X-ray machine in engineering course and biomolecules in science course were implemented using the proposed FACT pedagogy. At the end of delivery of the concepts, appropriate evaluation tests were carried out and the findings were summarized. The FACT pedagogy can help students enhance their thinking and understanding abilities, since the same complex concepts were discussed twice in backward and forward directions by the fusion of fishbone and computational thinking pedagogies. This can help the teaching community to easily solve or teach the complex problems or concepts while teaching engineering as well as science courses.

Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship and/or publication of this article.

Funding

The authors received no financial support for the research, authorship and/or publication of this article.

ORCID iD

B. Gopinath https://orcid.org/0000-0003-4717-5214

References

Barr, V., & Stephenson, C. (2011). Bringing computational thinking to k-12: What is involved and what is the role of the computer science education community?. *ACM Inroads*, *2*(1), 48–54.

Bryk, A. S., Gomez, L. M., Grunow, A., & LeMahieu, P. G. (2015). *Learning to improve: How America's schools can get better at getting better*. Harvard Education Press.

Gaul, C., & Kim, M. K. (2020). April). Conceptualizing computational thinking pedagogical content knowledge: An exploratory study [Paper presented]. *Society for Information Technology & Teacher Education International Conference* (14–23). Association for the Advancement of Computing in Education (AACE).

Hoyles, C., & Noss, R. (2015, 19–21 June). Revisiting programming to enhance mathematics learning (Proceedings). In Math+ Coding. Symposium conducted in the workshop of the Faculty of Education, Western University.

Istikomah, I. (2017). The influences of problem-based learning model with fishbone diagram to students' critical thinking ability. *Indonesian Journal of Informatics Education*, *1*(2), 171–179.

Ketelhut, D. J., Mills, K., Hestness, E., Cabrera, L., Plane, J., & McGinnis, J. R. (2020). Teacher change following a professional development experience in integrating computational thinking into elementary science. *Journal of Science Education and Technology*, *29*(1), 174–188.

Kong, S. C., Lai, M., & Sun, D. (2020). Teacher development in computational thinking: design and learning outcomes of programming concepts, practices and pedagogy. *Computers & Education*, *151*(1), 103872.

Kovpik, S. (2020). Developing critical thinking skills by students through active methods of the study of literature [Paper presented]. SHS Web of Conferences (*75*, 04003). EDP Sciences.

Latha, V., & Merlin, A. (2019). Fishbone diagram as a teaching tool. *The Journal of Nursing Trendz*, *10*(1), 21–24.

Lyon, J. A., & Magana, J. J. A. J. (2020). Computational thinking in higher education: A review of the literature. Computer Applications in Engineering Education, *28*(5), 1174–1189.

Papert, S. (1996). An exploration in the space of mathematics educations. *IJ Computers for Math. Learning*, *1*(1), 95–123.

Pérez, A. (2018). A framework for computational thinking dispositions in mathematics education. *Journal for Research in Mathematics Education*, *49*(4), 424–461.

Powers, J., & Azhar, M. (2020). Preparing teachers to engage students in computational thinking through an introductory robot design activity. *Journal of Computers in Mathematics and Science Teaching*, *39*(1), 49–70.

Prasad, K. D., Subbaiah, K. V., & Padmavathi, G. (2012). Application of six sigma methodology in an engineering educational institution. *International Journal of Emerging Sciences*, *2*(2), 210–221.

Qin, H. (2009). Teaching computational thinking through bioinformatics to biology students (Proceedings). *40th ACM technical symposium on* Computer Science Education(188–191).

Saad, A. (2020). Students' computational thinking skill through cooperative learning based on hands-on, inquiry-based and student-centric learning approaches. *Universal Journal of Educational Research*, *8*(1), 290–296.

Slameto, S. (2016). The application of fishbone diagram analysis to improve school quality. *Dinamika Ilmu*, *236*(1), 59–74.

Sufeni, M., & Fatimah, S. (2018). Using 'Fishbone Diagram' to teach writing discussion text to senior high school students. *Journal of English Language Teaching*, *7*(3), 548–555.

Sullivan, L., Mastrup, K., Davis-Welch, J., Forbes, C., Harvey, V., Hilberg, S., Hipolito, E., Kim, J., Panish, V., Salasin, E., & Wilson , J. (2020)). Supporting and making evident the practices of teacher education supervisors. In *The CCTE SPAN 2020 research monograph* (126–137). California Council on Teacher Education.

Viktorovna, P. O., & Viktorovna, D. M., 2020). Advanced industry technologies: Theory and practice of implementation in vocational education. *Process Management and Scientific Developments*, *33*.

Zuena, M. (2018). *Computational thinking skills in education curriculum* [Master's Thesis]. School of Computing, Computer Science, University of Eastern Finland.

Authors' bio-sketches

B. Gopinath is from Department of Electronics and Communication Engineering at Kumaraguru College of Technology in Coimbatore, Tamil Nadu, India.

R. Santhi is from Department of Biochemistry at PSG College of Arts & Science in Coimbatore, Tamil Nadu, India.