

## CDIO-based data structure practical coursebook

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**ABSTRACT:** There are several factors which affect the efficiency and effectiveness of learning. Some of those factors are the learning approach and the material. With the appropriate approach, learning can be more interesting and lessons can be better understood. Described in this article are the development and implementation of the learning material for a data structure course. The learning material is a practical coursebook incorporating the CDIO (conceive, develop, implement, operate) approach to learning. The method used for this development was based on the *The Systematic Design of Instruction* by Dick et al [1]. The product was developed and implemented for two data structure classes. The results show that the product was valid and ready for implementation. There were improvements in learning as shown by students' final scores and learning was more active.

### INTRODUCTION

In the Data Structure course at the State University of Malang, Indonesia there are two types of learning involved, viz. theory and practice. In theory, students learn about data structures and their implementation, while in practical learning they implement the data structures as software programs. In this course, students encounter problems in understanding the abstract concept of a data structure [2]. Many students get confused when they have to convert the data structure into a program [3]. The possible cause of this problem is traditional teaching which results in passive learning without a proper understanding on the lesson [4][5].

Another problem in this course is the learning material. For practical learning, the learning material consists of a practical workbook which has been used for a long time without modification or innovation. The book contains theory about a data structure, a demonstration exercise, and a very similar task to be solved by the student [6]. With a similar task to that in the book, students tend to just share the solution with each other, with minor modifications [3].

Based on these problems, a solution is needed to make learning more active, creative and innovative. The solution should cover the learning approach and learning material. The possible solution is to develop learning material embedded within a specific learning approach. The approach chosen was CDIO (conceive, develop, implement, operate) that was developed specifically for learning engineering. This approach was considered suitable for the Data Structure course. This approach has three main goals [7]:

- Understanding and deepening basic knowledge of the technical material.
- Produce a product and system through a creative and innovative process.
- Understand the importance and impact on real life of research and technological development.

With CDIO, the learning process is expected to be more active, innovative and engaging [8]. This can stimulate the interest of students in team-based learning and improve the quality of teaching [9]. Students are expected to understand the fundamental and abstract concept of a data structure and produce a program as a solution using a creative and innovative process. Students work in teams to share knowledge and develop putative solutions [10]. They can also relate the importance of technological development to real life.

### METHOD

The method in this research was adopted from the model of Dick et al [1]. In this model, there are ten main steps starting with analysis, such as learning objectives, basic and entry requirements. After the implementation of the model

a review is undertaken to discover the effect on the learning on the Data Structure course. The complete description of each phase is as follows:

- Identify instructional goals

The first thing is to identify learning objectives to determine what it is that students need to learn. In addition, it also identifies what students have to be able to do after the learning. On the Data Structure course, students should understand the basic knowledge and capabilities of data structure.

- Conduct instructional analysis

This step is a determination of the initial knowledge or skills that students need before they undertake a Data Structure course. The basic requirements are set in order to prevent a gap between students' understanding and the subject material. Students need to understand the basics of programming algorithms as initial knowledge for the Data Structure course.

- Identify entry requirements

The next step is to identify students' required behaviour and characteristics. Based on the earlier discussion, the traditional learning should be converted to a new approach. Learning material should be changed to be innovative. This learning material should support students to think innovatively and creatively when solving problems. It also pushes students to be more active in problem-solving.

- Write performance objectives

The fourth step is to identify specific and detailed objectives for the lessons. The data structure material is contained within a few chapters. Based on the first step (instructional goals), this step determines what students need to learn and have to achieve in each specific chapter.

- Develop criterion reference tests

In this step, the assessment instrument is developed to evaluate students' work. The instrument is developed based on learning or performance objectives identified at an earlier step. The evaluation is not only obtained from the final results of the programme, it also evaluates student learning appropriate to the CDIO approach. This ensures the evaluation is appropriate for the CDIO approach.

- Develop instruction strategies

This step establishes and determines the lesson plan, which consists of the learning approach, learning process and learning activities. The learning approach selected was CDIO. Every procedure of the approach should be understood by the lecturer or instructor. The approach is also embedded into the learning material to align the learning process with the learning objectives.

- Develop and select instructional materials

After the earlier steps, the learning material can be developed. The learning material should be appropriate for CDIO. Some points appropriate for this approach are:

- a) for each step of CDIO specific instructions to students for exploration and discussion as part of active learning;
- b) written descriptions as a link to instruction to encourage students to observe and explore the subject from other sources;
- c) examples of code programs to implement a data structure;
- d) exercises and case studies to be solved by students. This includes links to other sources to encourage students to explore and produce innovative solutions for problems.

- Conduct formative evaluation

After the draft of learning material has been produced, the next step is to conduct a formative evaluation. The aim of this step is to collect data for measuring product validity. In this evaluation there are three phases:

- 1) individual tests that involve three learners as material and media experts;
- 2) small-group test involving eight to 20 students;
- 3) a questionnaire about the learning material producing suggestions and comments as a basis for later revision.

- Revise instruction

The evaluation produces quantitative and qualitative data. The quantitative data are obtained from the questionnaire, while the qualitative data are obtained from suggestions and comments. The data obtained will inform the need for the improvements or modifications.

- Conduct summative evaluation

The final step is to implement the product. This implementation involved first-year undergraduate students who took the Data Structure course in one semester. It consisted of two classes, with a total of 69 students. Class observations during the learning process were conducted to obtain quantitative and qualitative data. Quantitative data obtained were task score averages and the qualitative data were based on observations of student progress on completing CDIO assignments.

## RESULTS AND DISCUSSION

The developed product is a practical coursebook for a CDIO approach to learning data structures. The book contains several chapters, each of which discusses a specific data structure topic. The theory covered in each chapter is brief, to make students not depend on only one source of learning material, and hence make them explore for further information. There are instructions covering each phase of the CDIO approach. These instructions are used as a sign for students to solve the problems in accordance with CDIO [11]. The instructions are represented with symbols for ease of recognition; as shown in Figure 1.

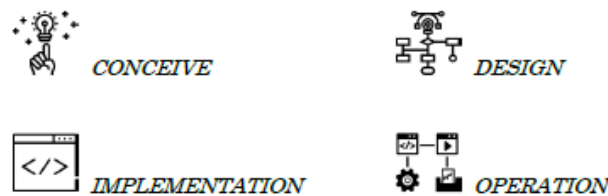


Figure 1: The symbols representing each CDIO phase [3].

Each symbol generally describes a CDIO phase, i.e. conceive, design, implement, operate. See Table 1 for details of the CDIO phases.

Table 1: CDIO phases.

CDIO phase	Instructional description
Conceive	<ol style="list-style-type: none"> <li>1. Read and understand the theory for a problem.</li> <li>2. Identification of pre- and post- conditions of the problem.</li> <li>3. Determine possible solutions.</li> </ol>
Design	<ol style="list-style-type: none"> <li>4. Analyse problem details.</li> <li>5. Determine the best solution for the problem.</li> </ol>
Implement	<ol style="list-style-type: none"> <li>6. Convert the solution into a program (coding).</li> <li>7. Test the program.</li> </ol>
Operate	<ol style="list-style-type: none"> <li>8. Present the program to the lecturer/instructor and other students, then explore other possible solutions through class discussion.</li> </ol>

There are several components to the practical coursebook, i.e. instructional guide, program examples, exercises and case studies.

### Instructional Guide

This provides a guide to using the book. Besides the symbols which represent each CDIO phase, there are descriptions of each symbol. The instructional description is shown in Table 1 [3]. Based on Table 1, there is a description of what the student should do in learning using the practical coursebook. The lecturer or instructor should monitor the students in order to ensure an appropriate learning process.

### Program Examples

Besides theory, there is also a program example for each chapter. The program example is in line with the topic of each chapter. With the program example as indicative of what is required, students are expected to produce another appropriate program. Figure 2 shows a program example for the chapter set.

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```

>>> A = set([0, 1, 2])
>>> B = set()
>>> 1 in A
True
>>> A & B
{}
>>> B.add(1)
>>> B.add(1)
>>> B.add(5)
>>> B
{1, 5}
>>> A & B
{1}
>>> A | B
{0, 1, 2, 5}
>>> A - B

```


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Figure 2: Example program in the chapter set.

### Exercises and Case Study

The coursebook contains exercises and a case study that students should finish. The tasks are not only presented in the book, there are links to other sources so that students can explore alternative material. An exercise and case study are shown in Figure 3. It can be seen that symbols are used for each exercise or case study. There are one or more symbols for each task indicating the work to be done.

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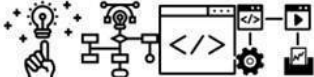


1. Open the following link:
 

[https://ocw.mit.edu/courses/electrical-engineering-and-computer-science/6-0001-introduction-to-computer-science-and-programming-in-python-fall-2016/lecture-slides-code/lec5\\_tuples\\_lists.py](https://ocw.mit.edu/courses/electrical-engineering-and-computer-science/6-0001-introduction-to-computer-science-and-programming-in-python-fall-2016/lecture-slides-code/lec5_tuples_lists.py)

  - a. Look and understand every list and tuple program examples.
  - b. Before trying to compile these programs on your IDE, determine the pre- and post-analysis of these programs.
  - c. After that, compile and run the programs one by one. Does the output match your pre- and post-analysis? Explain your program analysis.

**2.1 Case Study**



1. There is a list that contains square numbers between 1 to 20. Make a program to show the first five elements and last five elements from the list.

Figure 3: Example of an exercise and case study.

### Summative Evaluation

The practical coursebook has been implemented in two classes of the Data Structure course. The final score obtained was based on the assignment and final project. Based on their final score, 15 students (21.7%) passed with a very high score, 31 students (44.9%) with a high score, 11 students (15.9%) with a fair score, nine students (13%) with a low score, and three students (4.3%) with a very low score. Table 2 shows the score distribution for the two classes.

Table 2: Score distribution for the Data Structure classes.

Score range	Category	Class A	Class B	Total
85-100	Very high	8	7	15
75-84	High	17	14	31
60-74	Fair	6	5	11
50-59	Low	3	6	9
0-49	Very Low	1	2	3
Total students		35	34	69
Average score		78.6	76.4	77.5

The learning process was observed during the course. The learning was more active, because there was more discussion while the tasks were done. The tasks encouraged the students to discover other resources. Team working in computer programming helps foster analysis of algorithms and student creativity. Students not only produce the computer program, but also analyse the problem and design the solution. This is expected and appropriate for CDIO where stress is placed on active learning, teamwork, collaboration and problem solving.

Students felt the coursebook was of a new style and they did not have to depend only on the book. They can explore further to improve active learning [11]. The lecturer also felt satisfied that the coursebook provided a new style in learning, hence promoting student self-learning.

There are several items of research that support these findings. The student can search for materials according to the project requirements, and lead the project implementation process independently, hence turning passive into active learning [5][12-14]. The application of CDIO builds the personal foundation of practical ability, strong project development skills and innovative abilities in design, construction and engineering [12][15]. The application of CDIO in practice and training improve both the students' and teacher's abilities [16][17].

## CONCLUSIONS

The practical coursebook has been developed and implemented. The use of CDIO embedded in the book can be considered a new style of learning material. The impact of implementation of the coursebook has been good on student satisfaction, scores and learning. It produces an interesting learning process that improves active and self-learning.

Further research is necessary to better identify strengths or deficiencies of the book. It also can be adopted for other learning media platforms to produce new-style learning material. The implementation of CDIO in other subject areas, especially in engineering, is recommended given the benefit of this approach.

## REFERENCES

1. Dick, W., Carey, L. and Carey, J.O., *The Systematic Design of Instruction*. Pearson (2014).
2. Zhulin, L.I., A Method for Data Structure Course Design Based on CDIO Teaching Idea 2. The Course Design Based on CDIO Model. 418-421 (2017).
3. Wibawa, A.P., Dwiyanto, F.A., Widiyaningtiyas, T., Wirawan, M.I., Gunawan Iriyanto, W.S. and Ahmar, A.S., Utilization visualgo.net as a data structure learning media based on CDIO. *J. of Phys. Conf. Ser.*, 1028, **1**, (2018).
4. Dixit, R.K. and Yalagi, P.S., Visualization based intelligent tutor system to improve study of computer algorithms. *J. of Engng. Educ. Transformations*, 30, **3**, 157-163 (2017).
5. Cao, F-h., Reform of a Java curriculum based on a CDIO active project-driven method. *World Trans. on Engng. and Technol. Educ.*, 14, **1**, 129-135 (2016).
6. Junaidu, S., Effectiveness of multimedia in learning and teaching data structures online. *Turkish Online J. of Distance Educ.*, 9, **4**, 97-108 (2008).
7. Crawley, E.F., Malmqvist, J., Östlund, S. and Brodeur, D.R., *Rethinking Engineering Education*. (2nd Edn), New York: Springer (2014).
8. Mu, Y., You, D. and Dou, Y., CDIO training mode of programming ability for software engineering students based on ACM/ICPC competition standard. *Proc. 11th Inter. CDIO Conf.* (2015).
9. Chen, Y., Li, P., Zhou, H. and Fu, P., Evaluation method for CDIO project-based teaching, with total-process multi-assessment. *World Trans. on Engng. and Technol. Educ.*, 13, **3**, 291-295 (2015).
10. Lingling, G., Guowei, T., Yu, F., Jinghui, L. and Wanping, Z., Research and practice on CDIO-based application-oriented practical teaching system of computer major. *Proc. Inter. Conf. on Futur. Comput. Support. Educ. Res.*, 2, 24-29 (2012).
11. Dwiyanto, F.A., Pengembangan Bahan Ajar Berbasis CDIO untuk Struktur Data dengan Bahasa Python di Jurusan Teknik Elektro Universitas Negeri Malang. Universitas Negeri Malang. (2017) (in Indonesian).
12. Zu, Y. and Xu, M., Research on the teaching reform of a *Single Chip Microcomputer* course based on the concept of CDIO. *World Trans. on Engng. Technol. and Educ.*, 15, **2**, 169-173 (2017).
13. Wibawa, A.P., Suyono, Lantara, A.D., Purnawansyah, Haviluddin and Dengen, N., Using the CDIO framework to teach research methodology to informatics students. *World Trans. on Engng. and Technol. Educ.*, 16, **4**, 351-355 (2018).

14. Pham, P.A., Nguyen, M.D., Nguyen, L.Q., Nguyen, T.M. and Le, B.N., Learning computer programming in CDIO's team settings. *Proc. 10th Annu. Inter. CDIO Conf.* (2014).
15. Yang, C., Huan, S. and Yang, Y., Application and management of EPI-CDIO teaching for engineering students in local undergraduate colleges. *World Trans. on Engng. and Technol. Educ.*, 13, 3, 417-420 (2015).
16. Lin, G. and Tang, Y., Application of CDIO in practice and training of an engineering automation specialty. *World Trans. on Engng. and Technol. Educ.*, 13, 3, 407-411 (2015).
17. Liu, Z., An analysis of the curriculum for water supply and drainage, science and engineering, based on CCDIO. *World Trans. on Engng. and Technol. Educ.*, 13, 4, 582-588 (2015).