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# Development of Workbook to Enhance Students' Competency in Computer Networking Fundamentals

**Ian P. Benitez**

*Camarines Sur Polytechnic Colleges, Nabua, Camarines Sur, Philippines, 4434*

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**ABSTRACT** This study focused on the development of a workbook to overcome students' learning difficulties and to strengthen their competency in a computer networking course in the implementation of competency-based training at Camarines Sur Polytechnic College. The difficult networking skills were identified, a workbook was created using Backward Design, and an assessment of the effectiveness of the workbook in the learning process was carried out. A paired sample t-test on the findings of the pre-test and post-test showed a substantial increase in student performance. Post-test results showed that students had a high degree of competence with a passing rate of 98.6 percent. Moreover, with a grand weighted mean of 4.51, the workbook was found to be acceptable in terms of content, working example, and assessment. These results showed that the developed workbook was able to enhance students' competency in computer networking fundamentals.

## INTRODUCTION

In both developed and developing countries, Technical and Vocational Education and Training (TVET) plays a major role in shaping the core skills of trainees as a significant factor in employability. One of the reasons for the renewed interest in core skills is the growing access to Information and Communications Technology (ICT) and how it impacted the way services are delivered in the community (Comyn et al. 2015). In the Philippines, the government supplemented the formal school system by introducing the TVET system in response to the needs of various industries for skilled workers (Wu et al. 2019). The Technical Education and Skills Development (TESDA) began defining highly in-demand skills, developing competency-based training, and creating a national evaluation and qualification framework for different areas and disciplines called National Certification (NC). This move ensured high-quality execution of TVET programs in the country to meet the industry's expectations (Budhrani et al. 2018; Manalo et al. 2018).

With its implementation, CSPC moved towards its adoption and employed the framework in all relevant competency-based IT courses. However, in the first national evaluation that followed after the completion of the course, results showed that out of 34 students who took the Computer System Servicing (CSS) (TESDA 2013) assessment, only 16 students attained all the skills assessed, achieving a passing percentage of only forty-eight percent, which is considered a low competency level (Estecomen et al. 2019). Analysis of the overall results of the assessment showed that the area of competency where students performed poorly was in the field of computer networking. In an interview conducted with the students who took the test, the following responses were solicited:

1. The workstations, although physically connected, cannot be recognised in the network
2. They emphasised the lack of clear understanding on how network addressing influenced the connectivity of network devices
3. They stated the need to prepare an activity-oriented learning about the basic networking concepts and protocol implementations systematically associated with networking problems. This statement was supported by Bostan (2015), who emphasised that solving computer networking issues should be a significant component of computer network education.

With regard to the experience of the researcher as the trainer in computer networking courses, it is firmly believed that these difficulties demonstrated a lack of competency in the fundamentals of computer networks. The basic skills are

necessary for learners to master in order to perform their tasks effectively (Hailikari et al. 2008; Corritore et al. 2020). Hence, the supplementation of a workbook in fundamental computer networking was considered to be a solution to these prevailing difficulties in the learning process.

### Objectives

The goal of this study was to develop a workbook as a supplementary learning material for students taking computer networking courses. Specifically, this study (a) identified the essential networking skills to be incorporated in the workbook based on the recognised difficult competencies, (b) developed a workbook using Backward Instructional Design, (c) evaluated if the workbook enhanced the competency of the students, and (d) evaluated its level of acceptability in terms of contents, worked examples and assessment.

## METHODOLOGY

### Research Design and Setting

This study utilised a combination of descriptive and experimental design using one-group pre-test-post-test method. The study was conducted at Camarines Sur Polytechnic College, Philippines, and was participated in by the forty-eight (48) IT students and fifteen (15) IT faculty. In the study period, the student-participants were taking the course Network Administration and Maintenance. The selected class have the same knowledge level and ICT background.

### Data Collection

In gathering the relevant data for this study, the procedures employed included interviews, identification of networking competencies for workbook inclusion, pre-test and post-test for each module, and distribution of the questionnaire to the experts to assess the level of workbook acceptability.

#### *Interviews*

Participants were interviewed about the difficulties with the competency-based delivery of computer networking courses and were asked for feedback and expectations about the content of the workbook.

#### *Pre-test*

This examination also served as a diagnostic evaluation to assess the baseline measurement of students' performance and to recognise computer networking competency challenges. The assessment tasks covering the networking competencies recommended by TESDA included IP addressing, server computer installation and configuration, router configuration, accessing server resources, access point configuration, network printing, physical network configuration (structured cabling and crimping), and basic network troubleshooting.

#### *Pre-test-Post-test Evaluation*

The results of the post-test were associated with the pre-test to evaluate the following.

##### *Students' Achievement*

For each skill set, there were 10 evaluation tasks prepared. Using a rubric, the practical test was checked, with the lowest grade of 50 and a maximum of 100. The student should get a score of 95, a level set by the researcher, to be regarded as competent on a specific skill. Finally, to assess the students' achievement, a two-tailed paired sample t-test was conducted at a 0.05 degree of significance.

##### *Competency Level*

To evaluate the competency level of the students, the passing percentage for each skill assessed was calculated as follows:

No. of student-participant passers/total no. of student-participants * 100 (eq. 1)

Then the matrix formulated by Estecomen et al. (2019) to measure the level of competence of the students was adopted for each networking activity evaluated. Table 1 presents this competency level matrix.

#### *Experts' Acceptability of the Workbook*

The questionnaire was first devised to evaluate the level of acceptability of the workbook in

**Table 1: Competency level**

| *Passing percentage* | *Interpretation* |
|---|---|
| 75% -100% | - Very high competency level |
| 50%-74% | - High competency level |
| 25% -49% | - Low competency level |
| 0%- 24% | - Very low competency level |

terms of contents, worked example, and assessment. After that, the IT experts evaluated the workbook using a five-point Likert scale system.

### Crafting of Workbook's Contents

A structured approach is to produce instructional materials and involves a more established model to direct the process (Terano 2015). With its development, two instructional design frameworks were taken into account in the literature. Auditor et al. (2014) and Nicolas (2020) used ADDIE (analysis, design, production, implementation and evaluation) in the development of instructional materials for animal science and 10$^{th}$ grade physics courses, respectively. On the other hand, the instructional development effort of Whitehouse (2014), Jozwik et al. (2017), and Hosseini et al. (2019) implemented the Backward Design principles.

Due to the congruence of competence-based learning with the Backward instructional concepts, the contents of the established workbook were anchored in Backward Design. This design consists of three steps: (1) identifying the desired outcome, (2) determining acceptable evidence that validates the achievement of the learning outcomes, and (3) planning learning experiences that reflect on the activities and performance tasks that must be included in the workbook. Approaching this design guarantees outcomes and assessment as the centre of the planning process (Ontaneda et al. 2019).

## RESULTS AND DISCUSSION

### Diagnostic Assessment Result

Guskey et al. (2016) reported that the evaluation of previous learning of the student had a major role in the successful determination of the baseline data for instructions. Thompson et al. (2003) stressed that determining prior knowledge through assessment has a significant impact on the success of instructional development. The diagnostic evaluation helped to assess the content based on the difficult networking competencies found. It likewise measured the baseline performance of the students. Table 2 presents the results of the diagnostic assessment.

Table 2 reveals that only 29.2 percent of students passed IP addressing, so it was rated as the most difficult competency. This outcome complemented by the students' observation of learning processes and interviews in which they stated that the problems they experienced were linked to the logical design of the network. Other difficulties found were with installing servers and devices and network devices such as access points and routers, all about the logical side of network configuration. However, students performed satisfactorily on the physical network setup, with a 95.8 passing percentage.

**Table 2: Competency rate of students in the diagnostic assessment**

| *Competency* | *Pretest (Passing percentage)* |
|---|---|
| IP addressing | 29.2 |
| Installing server computer | 31.3 |
| Router configuration | 35.4 |
| Accessing server resources | 37.5 |
| Access point configuration | 39.6 |
| Network printing | 47.9 |
| Domain controller setup | 54.2 |
| Physical network configuration | 95.8 |
| Basic network troubleshooting | 62.5 |
| Average | 48.2 |

With a grand weighted mean of 48.2 percent, it is sound to say that students have a very low competency level in computer network prior to the use of the workbook. With these observations, further focus was placed on the logical network design of the following competences in the learning modules, that is, IP addressing, installing/configuring server computer, router, and access point configuration, accessing server resources, network printing, and domain controller setup. Foundations of physical network configuration were also discussed, but were limited to transmission media and structured cabling.

### Workbook Contents

The developed workbook provides a practical introduction to computer networking. The

incorporation of exercises in computer networking courses, as Sarkar (2006) emphasised, is advantageous for the successful learning of students. Nevertheless, the implementation of fundamental theoretical knowledge in these applications is essential because it enables students to apply for both technical and theoretical underpinning of the computer network (Ran 2012).

Three network competencies, such as setup computer networks, manage computer networks, and set up computer server, were included in the workbook. Table 3 presents the learning results, evaluation proof, learning plan, and topics of the learning module for the competency of "setup computer networks".

**Table 3: Workbook contents for setup computer networks competency**

| *Learning outcomes* | *Assessment evidences (practical activities)* | *Workbook learning plan (learning modules and worked examples)* | *Workbook learning modules* |
|---|---|---|---|
| Identify different network components and their functions in the network installation<br>o Apply the proper selection of media and connectors combinations for the jobo Observe and implement proper crimping procedures<br>o Understand the principles of Internet Protocol-related network information such as IP address, network address, broadcast address, and subnet mask and how they influence network communicationo Assign IP address to the host given the required network informationo Apply the proper subnet masking when performing CIDR system<br>Configure a DHCP server to automatically assign network information to the clients | In a particular network task, have the students identify and decide on the network components to be acquired for the needed installation process.<br>Case study: Design a network diagram indicating the type of cables of connectors used to interconnect network devices<br>Case study: Design a network applying particular network information to setup hosts based from the computed IP information<br>Case network scenario: Using a predefined network, enable one computer as DHCP server and turn other to clients, and allow them to request network information to the server such as IP address, subnet mask, gateway, and domain name server | o Learning module that explains the network components and their functionso<br>Worked example that demonstrates the selection of network devices when planning and designing a network.<br>o Learning module activity that lets students use simulator to demonstrate the different effects of types of cabling to interconnected deviceso Infographic of proper crimping procedures<br>o Learning module that outlines the process of IP address computationo Identify the parts of an IP addresso A worked example to perform the following:Ï%<br>Finding network address, broadcast address, and host idÏ%<br>Apply subnetting in a network<br>o Learning module that presents the concepts of DHCP and outlines the process of configuring DHCP server, and the process of acquiring network information from the client sideo<br>Simulation of network DHCP process through demonstration using simulators | *Network components and their applications to different network setup*<br>*Network Media*<br>*IP Addressing*<br>*Dynamic Host Configuration Protocol* |

The prerequisite topics were first addressed in the learning plan to provide continuity, prevent gaps, and support prerequisite knowledge and skills. The learning outcomes were specified by each competency and the worked practice contained assessment-evidence and networking problems.

## Evaluation Results

### *Students t-Test Result*

A paired-sample t-test was conducted using a two-tailed test at a 0.05 level of significance to assess the achievement of students on the three competencies. Table 4 indicates the significant statistical difference in the test results after using the workbook, implying that using the workbook enhanced the student-participants' performance in computer networking fundamentals. The improvement of learners' performance was consistent with the findings of Sarkar (2006), Terano (2015), and Nicolas (2020) that utilising well-developed instructional materials is effective in enhancing learners' competencies.

### *Competency Level of the Students*

Table 5 presents the competency level of student-participants before and after the utilisation of the workbook. A low level of competence was demonstrated by the pre-test performance, with an overall passing percentage of just 48.2 percent. Most skills assessed showed a drop in the level of competence, especially IP addressing. Nonetheless, pre-test results showed that the students attained a very high competency level on physical network configuration. Post-test results, on the other hand, showed that the student-participants' output improved substantially with an average passing rate of 98.6 percent, interpreted as a very high level of competence.

**Table 4: Comparison of students' pre-test and post-test results on the assessed skills**

| *Competencies* | *Skills assessed* | *Paired difference Mean* | *t* | *df* | *Sig* |
|---|---|---|---|---|---|
| Pre-test-Post-test | | | | | |
| Setup computer networks | Physical network configuration | 12.52 | 7.00 | 47 | .000* |
| | Network printing | 9.10 | 5.25 | 47 | .000* |
| | Access point configuration | 8.79 | 5.57 | 47 | .000* |
| | Router configuration | 8.27 | 5.72 | 47 | .000* |
| | IP addressing | 8.75 | 4.97 | 47 | .000* |
| Setup computer servers | Installing server computer | 9.60 | 6.26 | 47 | .000* |
| | Domain controller setup | 12.77 | 7.08 | 47 | .000* |
| | Accessing server resources | 9.29 | 6.72 | 47 | .000* |
| Maintain computer networks | Basic network Troubleshooting | 9.08 | 5.77 | 47 | .000* |

* *Significant at $p < 0.05$*

**Table 5: Comparison of student-participants' competency level**

| *Skills assessed* | *Passing percentage* | *Interpretation* | *Passing percentage* | *Interpretation* |
|---|---|---|---|---|
| | *Pre-test* | | *Post-test* | |
| Physical network configuration | 95.8 | Very high | 100.0 | Very high |
| Domain controller setup | 54.2 | High | 97.9 | Very high |
| Network printing | 48.0 | Low | 100.0 | Very high |
| Access point configuration | 39.6 | Low | 100.0 | Very high |
| IP addressing | 29.2 | Low | 95.8 | Very high |
| Installing server computer | 31.3 | Low | 100.0 | Very high |
| Accessing server resources | 37.5 | Low | 95.8 | Very high |
| Basic network troubleshooting | 62.5 | High | 100.0 | Very high |
| Average | 48.2 | Low | 98.6 | Very high |

### *Acceptability of the Workbook by the IT Experts Evaluators*

Table 6 shows the evaluation results of the IT experts on the workbook. With a weighted mean of 4.49, 4.61 and 4.42 respectively, in terms of material, worked example, and evaluation, they agreed that the workbook provides substantial content that meets the critical skills needed in the configurations of basic computer networks. In terms of worked examples, the IT experts strongly agreed that the workbook provided substantial activities and indicated that the workbook aided them in teaching fundamental networking courses. This is evident from their reflective statements, that is, "Due to the systematic sequencing of worked practices, students were able to confidently move to the next learning modules since all the prerequisite skills were acquired already", and "a great deal of skills improvement was accomplished on IP addressing because of the detailed explanation of concepts coupled with analogies and scenarios." The faculty-respondents likewise agreed that the workbook's assessment provides case-based scenarios that resemble real-world problems that they can replicate in their future jobs. The overall mean of 4.51 showed that they strongly agreed that the workbook was capable of enhancing the learners' competency.

## CONCLUSION

This study developed a workbook on computer networking fundamentals to respond to the

**Table 6: Acceptability level of the workbooks**

| *Item* | *Σ Wm* | *Verbal interpretation* |
|---|---|---|
| ***A. Contents*** | | |
| 1. The topics support and extend a student's knowledge in fundamentals of computer networking. | 4.42 | Agree |
| 2. The fundamental concepts were presented in a way that enables understanding of more complex networking topics. | 4.29 | Agree |
| 3. The topics, worked examples and assessments support the learning outcomes. | 4.52 | Strongly agree |
| 4. The topics are relevant to the learning situation. | 4.29 | Agree |
| 5. The lessons are sequenced in a way best suited for students' level of understanding. | 4.33 | Agree |
| 6. The illustrative examples given are clearly presented and sufficient to understand the concepts. | 4.63 | Strongly agree |
| 7. The lessons span the learning stages from initial exposure to an idea to understanding and application. | 4.79 | Strongly agree |
| 8. The contents were designed to encourage the upsurge of interest of s tudents on the subject matter while working independently. | 4.63 | Strongly agree |
| **Weighted Mean** | **4.49** | **Agree** |
| ***B. Worked Example*** | | |
| 1. The worked examples foster active involvement and stimulate thinking. | 4.79 | Strongly agree |
| 2. The worked examples reinforce the development of skills in networking tasks. | 4.65 | Strongly agree |
| 3. The worked examples discuss systematically the sequence and steps/ approaches in all procedures being studied. | 4.52 | Strongly agree |
| 4. The worked examples simulate real-world networking scenarios and problems. | 4.42 | Agree |
| 5. Students were provided with a wide range of learning activities aligned to the objectives of the learning modules. | 4.67 | Strongly agree |
| **Weighted Mean** | **4.61** | ***Strongly agree*** |
| ***C. Assessment*** | | |
| 1. The assessment questions measure the attainment of learning outcomes. | 4.35 | Agree |
| 2. The assessment includes activities that reflect real-world networking problems. | 4.40 | Agree |
| 3. The assessment includes questions to stir critical thinking and contains a variety of situation strategies. | 4.52 | Strongly agree |
| **Weighted Mean** | **4.42** | **Agree** |
| **Grand Weighted Mean** | **4.51** | **Strongly agree** |

*Legend:* Rating (4.5-5.0: Strongly Agree, 3.5-4.49: Agree, 2.5-3.49: Undecided, 1.5-2.49: Disagree, 1.0-1.49: Strongly Disagree)

needs of enhancing students' computer networking competence. The content was designed on the basis of the difficult networking competencies found. The structure of the workbook was anchored on the training regulation for TESDA's CSS and the Backward Instructional Design was applied in the content development. Evaluation results showed that the workbook's utilisation aided in enhancing the skills in all the given competencies. Achieving a grand weighted mean of 4.51 in the measurement for acceptability level, the IT experts strongly agreed that the workbook was acceptable in terms of contents, worked examples and assessment. As indicated in the students' pre-test and post-test results, it was evident that they had achieved performance enhancement and improved competency level in all the skills measured. From these findings, the workbook satisfied all the requirements for utilisation in fundamental computer networking courses.

## RECOMMENDATIONS

In the future, the use of the control group in the experiment may be explored. To further verify the results of the evaluation, the findings of the National Competency Assessment (NC 2) taken after completion of the program can be used. Study participants should also be expanded, including those who are enrolled in TESDA. Finally, the workbook can be submitted as instructional material for ICT-related courses to respond to the policy of CSPC to utilise competency-based learning resources for students training.

## REFERENCES


Auditor E, Naval DJ 2014. Development and validation of tenth grade Physics modules based on selected least mastered competencies. *International Journal of Education and Research*, 2(12): 145-152. www.ijern.com.

Bostan A 2015. Teaching computer networks: Theory and problem solving. *Journal of Advances in Computer Networks*, 3: 299–302. https://doi.org/10.18178/JACN.2015.3.4.186.

Budhrani KS, D'Amico MM, Espiritu JLD 2018. Developing a skilled workforce through technical and vocational education and training in the Philippines. In: RL Raby, EJ Valeau (Eds.): *Handbook of Comparative Studies on Community Colleges and Global Counterparts.* Springer International Handbooks of Education, pp. 693-718. doi: 10.1007/978-3-319-38909-7_28-1.

Comyn P, Brewer L 2015. International Labour Organization 2015. *Integrating Core Work Skills into TVET Systems: Six Country Case Studies*. International Labour Office, Skills and Employability Branch, Employment Policy Department, Geneva: ILO.

Corritore C, Love B 2020. Redesigning an Introductory programming course to facilitate effective student learning/ : A case study. *Journal of Information Technology Education: Innovations in Practice*, 19: 91–135.

Estecomen LE, Libutaque MS, Libutaque LP 2019. Industrial Technology students competency level under the Ladderized Education Program (LEP). *Journal of Physics: Conference Series*, 1254(1): 1–8. doi:10.1088/1742-6596/1254/1/012028.

Guskey TR, Mctighe J 2016. PRE-ASSESSMENT/ : Promises and Cautions. University of Kentucky UKnowledge, *Educational, School, and Counseling Psychology Faculty Publications*.

Hailikari T, Katajavuori N, Lindblom-Ylanne S 2008. The relevance of prior knowledge in learning and instructional design. *American Journal of Pharmaceutical Education*, 72(5): 1–8. https://doi.org/10.5688/aj7205113.

Hosseini H, Chalak A, Biria R 2019. Impact of backward design on improving Iranian advanced learners' writing ability: Teachers' practices and beliefs. *International Journal of Instruction*, 12(2): 33–50. https://doi.org/10.29333/iji.2019.1223a.

Jozwik S, Lin M, Cuenca-Carlino Y 2017. Using Backward design to develop service-learning projects in teacher preparation. *New Waves-Educational Research and Development Journal*, 20(2): 35–49.

Manalo JPA, Caguicla AR, Dimalaluan JMA, Macatangay JNG, Robles SMG, Felicen SS 2018. Effectiveness of TESDA National Certification to cruise line operation in culinary arts graduates of 2015 and 2016. *Journal of Tourism and Hospitality Management*, 15(1): 124–135.

Nicolas HJ 2020. Development and Pre-use evaluation of instructional materials in undergraduate animal science courses for agriculture programs. *International Journal of Educational Sciences*, 30: 29–39. https://doi.org/10.31901/24566322.2020/30.1-3.1137.

Ontaneda Rea M, Sánchez Román JL 2019. Implementing backward design to improve students' academic performance in EFL classes. *Espirales Revista Multidisciplinaria de Investigación*, 3(24): 42-50.

Ran Z 2012. Exploration on the key issues of practical teaching reform of computer network. *Energy Procedia*, 17: 1914–1919. https://doi.org/10.1016/j.egypro.2012.02.332.

Thompson R, Zamboanga B 2003. Prior knowledge and its relevance to student achievement in Introduction to Psychology. *Teaching of Psychology*, 96-10. https://doi.org/10.1207/S15328023TOP3002

Sarkar NI 2006. Teaching computer networking fundamentals using practical laboratory exercises. *IEEE Transactions on Education*, 49(2): 285–291. https://doi.org/10.1109/TE.2006.873967.

Terano HJ 2015. Development and acceptability of the simplified text in differential calculus for engineering. *Journal of Multidisciplinary Studies*, 4(2): 106–126. https://doi.org/10.7828/jmds.v4i1.851.

TESDA 2013. *Training Regulations: Computer System Servicing NC II. Amended December 2013*. Philippines: TESDA.

Whitehouse M 2014. Using a backward design approach to embed assessment in teaching. *School Science Review*, 95(352): 99–104.

Wu Q, Bai B, Zhu X 2019. Technical and vocational education and training in the Philippines: Development and status Quo. In: B Bai, Paryono (Eds.): *Vocational Education and Training in ASEAN Member States, Perspectives on Rethinking and Reforming Education*. Singapore: Springer, pp. 155–171. https://doi.org/10.1007/978-981-13-6617-8_7.

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