Critical Thinking and Computing Project in Computer Studies Postgraduate Methods Course: Technology Perspective

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ABSTRACT

This paper investigates the level of engagement of critical thinking skills to the five-step problem solving process in postgraduate project development in a computer studies method course at the University of Botswana. It employed qualitative document analysis to analyse documentations submitted by the 21 postgraduate diploma students as part of their coursework for a computing methods course. The development of critical thinking skills; notably making well-informed decisions, explain own reasoning and solving unknown problems during project development is a very crucial component of our methods course. The findings indicate that the students lack critical thinking skills that are necessary for problem-solving for this level. This paper then proposes some key critical thinking questions that the students could ask during the project development process in order to remain focused on key issues during the whole development process from problem analysis to the final implementation stage. These questions will foster the development of the necessary lifelong critical thinking skills that students should master for their work. This implies that there is need for a change in our methodological approach to the teaching of this section of the course.

Keywords: Critical Thinking, Project Development, Computer-Based Problems, Technology Perspective, Problem-Solving Process

INTRODUCTION

Problem-solving in computing projects has always been a problem for novices (Lahtinen et al. 2005; Sarif & Shiratuddin 2009). In our postgraduate methods course in computer studies, individual students are required to complete a project to develop a computer-based solution to a problem that they identify themselves. They are required to go through the five-step process methodology of problem analysis, problem understanding, decision making, solution design, and lastly, implementation. Current observations (Reinstein & Lander 2009; Shafique & Rao 2006; Shannon & Bennett 2012; Snyder & Snyder 2008; McMahon 2009; Peter 2012) indicate that the students do not fully employ critical thinking skills in the five step process of problem solving. The real problem is that they lack critical thinking skills which are necessary to the understanding of the problems, and to the design and implementation of the solutions. Thinking critically is a skill that has to be learnt over a period of time. To develop this skill, the student has to ask himself questions time and again about his own thinking.

The project is a crucial component of the methods course. It teaches the systems approach to solving computer-based problems. The project involves selecting application areas that include hotel bookings, airline reservations, library systems, stock control, and other similar systems, and going through the five-step process to provide a solution to the problem. It is highly encouraged that students study this problem-solving approach within the context of an organisation.

There is no one-size-fits-all solution for the same type of application areas in information systems. Each organisation "has got its own problems and organisational and operational structures, and needs different kinds of solutions to problems that may arise within it" (Laudon & Laudon, 2002, pg. 343). Because these organisations are different, there is need for the analyst to employ good critical thinking skills in the analysis of problems and design of solutions.

In computer science, we can think of problem-solving as a five step process *(Refer to Figure 1)*. The first step is called problem analysis. During this stage the problem is defined and narrowed considerably. This is done to describe the objectives of the current system, and to find out exactly what the problem is. The second step, which is problem understanding, is to gather and analyse information, helping to understand the problem better and to divide the problem into manageable sub-problems. Then follows the decision-making step, in which all possible solutions are looked at, objectives and feasible solutions are debated and the best one is selected. By recognising that a large number of solutions exist in the environment, our goal is to capture the most correct solution from the many possibilities. The chosen solution to the problem is then designed in the fourth step. Hardware and software requirements are specified, as well as the method of solution. Lastly, implementation follows where the designs are developed, tested, and the whole system is evaluated (Laudon & Laudon, 2002).This problem-solving approach is used to guide systems analysts and software developers to carry out their work and provide solutions in a systematic way.

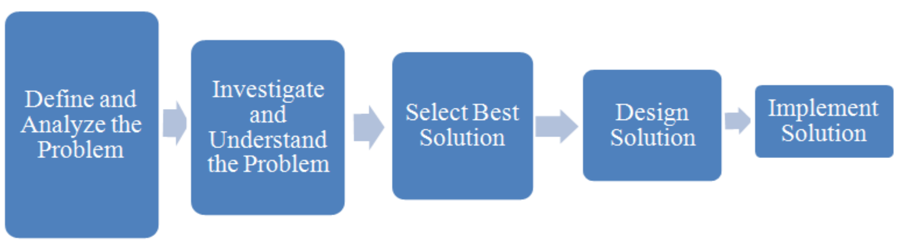

Figure 1. The Problem-Solving Funnel of Real-World Decision Making. Adapted from Laudon & Laudon (2002: 337)

This study seeks to highlight the importance of critical thinking during the five-step process of project development. During all the five-step process methodology, the students' documentations have to show that they have made well-informed decisions about what has to be done next. They should be able to explain their own reasoning, and thirdly; be able to solve unknown problems, i.e. problems that are similar to ones that they have seen before but have not worked on. In this work, we concentrate on the technology perspective. The other perspectives that business problems can be approached from are organisational and people perspectives. The technology perspective emphasises the "firm's hardware, software, telecommunications and database as sources of business problems and the ways in which they can contribute to a solution" (Laudon & Laudon 2002:339).

This study will answer questions related to "Which computer education competences are required for students to master critical thinking skills in computing project development?" and "Which reflective questions should students ask so that they remain focussed on key issues in project development?" It is our hope that these questions will contribute to the employment of critical thinking skills in computer education project work. The first part of

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the paper will explain the role of critical thinking in problem solving and in project development. Our methodology will follow. We will suggest important critical thinking questions that novices have to go through and ask during the whole process so that they develop the necessary critical thinking skills necessary for their work.

CRITICAL THINKING IN PROBLEM SOLVING

"Critical thinking is the identification and evaluation of evidence to guide decision making. A critical thinker uses broad in-depth analysis of evidence to make decisions and communicate his/her beliefs clearly and accurately" (Ennis, 1993:3). It is that "mode of thinking about a subject, content, or problem in which the thinker improves the quality of his or her thinking by analysing, assessing, and reconstructing it" (Allen & Stroup, 1998:180). A critical thinker has the ability to "identify problems" and "devise solutions" for problems, "construct and support arguments"; "classify and analyse data"; "integrate information and see relationships", "suspending beliefs and remaining open to new information" (Gelder, 2001; McMahon, 2009; Peter, 2012; Shannon & Bennett, 2012)(Duran 2012; Bailin 2002)

Students demonstrate that they are thinking critically by raising vital questions and formulating them clearly; "consider the context, justify their answers and analyse their own thinking in terms of clarity, accuracy, relevance, logic and fairness" (Choy & Oo, 2012: 199). They have the ability to focus on a question. They have the ability to identify a problem, then formulate criteria for judging possible solutions to the questions; and then keep the situation in mind, and also write down all possible problems and solutions to these problems. All the decisions are justified to the extent possible. The other viewpoints are equally considered.

In computer education, critical thinking plays a very important role for problem solving, especially in project development. Each of the five-step problem-solving process requires one to think about own thinking to be able to analyse and describe existing systems and understand what the problem is, to make proper decisions, design the right solutions and implement them. Our students need to have critical thinking skills if they are to develop the right solutions to computing problems. These skills need to be employed during the whole development of the software development cycle, or least students should strive to employ these skills to their capabilities. Tan, Turgeon, & Jonassen, (2001: 97) proposed that one must "provide novice problem-solver" with the critical skill of argumentation. Because there is no best solution, the learners "should form an argument against their preferred choices and reasons against alternative solutions" (Tan et al., 2001:97).

The starting point for critical thinking is a problem, and every problem requires a solution. Although solving a problem requires many skills, critical thinking is a central skill, though not the only one required for problem solving. To emphasize critical thinking is in no manner to minimize the importance of other forms of cognition. We focus on critical thinking in this study because we think it is extremely important and largely ignored during problem solutions in project work.

Critical thinking skills are necessary to plan, conduct and manage projects, solve computer-based problems, and make informed decisions using appropriate digital tools and resources. Project development is probably the most important work that students in computing disciplines will do during their one-year postgraduate diploma course. The project seeks to assess systems development in a practical manner. It tests virtually all areas of computing education. The students, working with business organisations should produce a solution system after a thorough critical thinking analysis on every stage of the development life cycle. Critical thinking in computing problem-solving entails the sustained suspension of judgement with an awareness of multiple perspectives and alternatives. It involves:

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1. Maintaining doubt and suspending judgement
2. Being aware of different perspectives
3. Testing all alternatives (Laudon & Laudon, 2002; Voskoglou & Buckley 2012)

The best protection is to engage in critical thinking analysis throughout the problem-solving process. The most frequent error in problem solving is to arrive prematurely at a judgement about the nature of the problem before a thorough analysis. By doubting all solutions at first, and refusing to rush to a judgement, the analyst creates the "necessary mental conditions to take a fresh, creative look at the problems, and keep open the chances of creative contributions" (Laudo n& Laudon, 2002, pg. 339).

In our methods course, the students select small businesses enterprises in the local community for the development of computer-based solutions to fit the needs of the enterprise's problem. The solution must be implemented using a programming language of choice or any other appropriate software package, and should at least include some program listings, documentation of the program code with appropriate algorithm descriptions of subroutines and procedures and interrelationships between modules. The critical thinking skills are seen at work during the whole problem-solving exercise.

METHODOLOGY

Target Population

The target population for this study consisted of 21 (14 female and 7 male) students doing our methods course in the academic year of 2012-13 at the University of Botswana. The unit of analysis was the individual student documentations. The students had different educational backgrounds, though all of them have degree qualification in computing disciplines. They had bachelor's degrees either in information technology, business information systems, information systems and computer science. They were taking a postgraduate diploma qualification in education, and this course mainly focused on micro-teaching and practical work so that they can practice at senior secondary school. Each one of the students had a personal computer to use during the whole project period in the laboratory, and also could use personal laptops during other times. Software for their use is also easily available. Each one of them used Microsoft Word for the documentation, spreadsheet and/or a either a database package like Microsoft Access and MySQL, or a programming language of their choice. Students were encouraged to choose their own familiar software to use on their solutions because the instructors did not want them to spend too much time on learning some unfamiliar software. Since these students have completed a qualification in computing disciplines, they are already familiar with a variety of software. Since the choice of software was also a critical skill competence, the instructors could not interfere in its selection.

Data Collection

Although some observations were done during the period the students were doing their projects, the main data collection method was document reading, and this was done after the submission of the project documentations. According to (Marshall 2006), document reading and analysis describes the form or content of written material in which each data sources has to be analysed. The students were given an open inquiry assignment to do as a project for the whole month of April 2013; a total of 10 hours. They could also work on the projects during other times that were not recorded, and were different depending on individual students. Before the month of April, the students, together with the instructor, had held discussions about the five-step process for three hours. These discussions were to familiarise them with the process. The students met twice a week with the instructor, the first meeting was 1 hour

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and the second meeting was 2 hours. They were then asked to choose their individual topics. No two students could work on the same topic. Example broad topic areas were stock control, asset management, and point of sale, transport management, hotel reservations, hospital administrations, and other similar systems.

Table 1. Some Critical Thinking Skills Competences in Computing Project Development in Methods Course

Step	*Major Critical Thinking Competences in Project Development*
Problem Analysis	1. Description of existing solution to the problem 2. Identification of problems/sub-problems in a system 3. Definition of problems/sub-problems 4. Formulation of objectives of the system 5. Identification of type of the problem/sub-problem
Problem Understanding	1. Identification of the causes of the problem 2. Explanation in own words the problem 3. Understanding of each of the sub-problems
Decision Making	1. Justification for selecting software/hardware for providing the solution 2. Description of other possible solutions, including reasons 3. Required changes and reasons 4. Evaluation of other possible solutions
Solutions Design	1. Identification of operational processes for I/O 2. identification and descriptions of system requirements 3. Identification and descriptions of software requirements 4. Outline the overall plan with reasons 5. Outline the method of solution and algorithms 6. Describe system security requirements
Implementation	1. Provide working solution, including algorithms, data entry, output forms, including reasons 2. Outline comprehensive test strategy and plan 3. Provide user and technical documentation 4. Outline recovery procedures in case of failure

They were then required to provide a computer-based solution following the problem-solving steps. This computer-based solution requires extensive documentation for all the stages during the project work. It is this documentation that was used as a basis for individual document reading; the data collection used in this work. Although other objectives were assessed during this period, this work only focused on critical thinking by the students during the development of their work. All the students managed to submit their project documentation before the due date. All the material related to critical thinking in all the five steps of the project development was copied to a word processor (Refer to Table 1). Each of the documentations was scrutinised to see if the student had employed critical thinking skills in the solution documentation; all from problem analysis to implementation.

Document Analysis Criteria

Four criteria were established for rating each of the critical thinking competencies in Figure 1. These were "none," "little," "medium," or "extensive". “None” was used to indicate that the student did not employ any critical thinking on a competence. “Little” was used to

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indicate that there was minimal critical thinking on a chosen competence. "Medium" meant that there was average critical thinking employed. "Extensive" was used to indicate well-informed decisions, good explanation of reasoning, and being able to solve new problems. For instance; on Step 1 (Problem Analysis), the first competence to look at on our rating was "Description of existing solution to the problem". Each section was read to find out if the description fitted into "none," "little," "medium," or "extensive". These would be summarised to establish the general level of critical thinking criteria set by the instructor. Each one of the competencies would be summarised accordingly; and the general levels of critical thinking analysis would be established from the competency chosen in this work. We have used the following critical thinking competences for data analysis, a priori coding scheme that is mainly used by examination boards in school computing disciplines for computing project work. The competences in Table 1 below are what the authors feel form the core in which critical thinking can be tested.

RESULTS FROM THE PROJECT DOCUMENTATIONS

Individual project documentations by the students were analysed by individual steps (Refer to Table 1.) in problem documentations. The major critical skills competences that are required during all the steps of project development are listed against the stages/steps. Although there was no requirement for the students to follow an exact order in the project documentation, it was expected that their documentations will answer the basic competences required for this work, as is expected in any computing problem-solving exercise, and according to the type of problem selected by the student. General trends and patterns were observed from each step with all the project documentations. The results are summarised below, and the table that follows has the data for the number of occurrences for each of the criteria used for each competence on each step.

Problem Analysis

Most students chose application areas and identified the problems accurately. All the documentations had some narrative description of how the current system is working, but without data flow diagrams and system flowcharts. Some only had some background to the organisation and the nature of the problem to be solved, without the order the processes are carried out, any descriptions of data entry into the system, files, operations, or reports. Most of the work failed to then divide the problem into sub-problems.

Table 2. Problem Analysis

S/N	*Competence*	*None*	*Little*	*Medium*	*Extensive*
1	Description of existing solution to the problem	0	15	5	1
2	Identification of sub-problems in the system	1	16	2	1
3	Definition of sub-problems	1	16	3	1
4	Formulation of objectives	2	15	3	1
5	Identification of the type of problems	7	12	2	0

There is need to take time to identify all the problems and how the whole system operates, and to then document them comprehensively; otherwise if the current system is not known, it will become virtually impossible to provide a convincing solution that will do away with the

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existing problem. The objectives were only listed either in business terms only or computer-related terms only. These objectives are the guidelines for what is going to be the solution, and will help in the evaluation of the new system later. Generally, most students had “little” critical thinking skill level in problem analysis.

Problem Understanding

It was noted that most of the work did not provide some documentation on the causes and nature of the problem, how data is collected, stored, processed and the nature of reports currently produced by the organisation, simplicity of the system, as well as the ease of data entry into the system. There were no realistic drawbacks of the current system, the advantages and disadvantages are given, but they are not very clear, e.g. writing “it is fast”, “It is accurate” without really being specific does not account for a clear evaluation of the system. There were no clear reasons of why the system was not working properly, and any considerations that can make it better. There is a common problem of misunderstanding between evaluation and analysis of the system. Also, there was very little consideration of current documentation used by the organisation.

Table 3. Problem Understanding

S/N	*Competence*	*None*	*Little*	*Medium*	*Extensive*
1	Identification of the causes of the problem	2	17	2	0
2	Explanation in own words the problem	3	14	4	0
3	Understanding of each of the sub-problems	4	14	3	0

Decision Making

Students are most likely to choose software that they are familiar with. Not much consideration of the strengths and weaknesses of the software are given precedence.

Table 4. Decision Making

S/N	*Competence*	*None*	*Little*	*Medium*	*Extensive*
1	Justification for selecting software/hardware for providing the solution	5	13	2	1
2	Description of other possible solutions, including reasons	3	16	2	0
3	Required changes and reasons	1	12	8	0
4	Evaluation of other possible solutions	3	16	1	0

Hardware selection did not pose problems, although there is need for the justification of the selection of some of the hardware components like which type of printer, processor, memory, camera, bar code reader; so that there is compatibility. There was also a problem of selecting the right hardware for the software selected. Students fall into a trap of believing that their proposed solution is the only method of solution. They forget that there are alternatives. These alternative solutions though do not look satisfactory first time, but may always be worthwhile to critically analyse each one of them before a final decision is made. These other alternative solutions also have to be evaluated to measure their strengths and weaknesses.

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Design

Most students could identify various useful software and hardware for their work, and the reasons for selecting a few of them. The most common mistake is to leave out the operating system software. They designed some data entry forms, reports and database tables and relationships, some pseudo code structures and program flowcharts. There is no consideration of the suitability of the user interface, design of formulas for the database tables and queries, validation checks and a test strategy. Although it is crucial to have a plan of action, very few students realise its importance and proceed to use Gantt chart. No Pert charts were used in any of the documentations.

Most students had separate modules in their work, and somewhat showed how they could work together. The main problem again; like in system description; was that there is no clear explanation of use of certain input and output procedures and forms, processing steps and storage requirements. The explanations of choice and type of peripherals would lessen the work on implementation. Some students had diagrams of structure charts and program flowcharts that may be useful during this part of the documentation, but without a clear flow of processes.

Table 5. Solution Design

S/N	*Competence*	*None*	*Little*	*Medium*	*Extensive*
1	Identification of operational processes for I/O	2	14	4	1
2	Identification and descriptions of system requirements	0	15	6	1
3	Identification and descriptions of software requirements	0	13	6	2
4	Outline the overall plan with reasons	2	17	2	0
5	Outline the method of solution and algorithms	2	16	3	0
6	Describe system security requirements	14	6	0	1

Implementation

The majority of students spend most of their time working with the software package or programming language that will provide the solution to the problem. They spend most of the time on building their solution.

Table 6. Implementation

S/N	*Competence*	*None*	*Little*	*Medium*	*Extensive*
1	Provide working solution, including algorithms, data, entry, output forms, including reasons	0	18	3	0
2	Outline comprehensive test strategy and plan	2	15	4	0
3	Provide user and technical documentation	0	13	6	2
4	Outline recovery procedures in case of failure	12	6	3	0

The main problem here is that the solutions do not cater for most of the objectives, or they try to "smuggle" some objectives that were not included originally. Some of the data entry forms, as well as the output forms, and algorithms for the solution are left out. Even the interface is poorly done, that there is no consideration for the type of user for the system being implemented.

Testing is done but the test strategy rarely provided. Without a test strategy, some of the test cases are left out, and errors still remain in their solutions. The majority only tests for normal data without giving any considerations for abnormal and extreme data testing. Recovery procedures are rarely included in case of system failure.

DISCUSSION

The results of the document analysis were presented in accordance with the data extracted from the documentation by the students, and also by each of the steps in the problem solutions. In general, the students lack critical thinking skills that are necessary for their work during all the steps of project development. They do not question appropriately on key issues on each step. The results above indicate that they leave quite substantial detail in the documentations. They end up providing unnecessary details, leaving out some key information that will help in the development of the project.

Computer education students have to be able to make "well-informed decisions"(Thomas 2011)from problem analysis to implementation. The results show that this critical thinking skill of making well informed decisions has not been mastered. They cannot make decisions on selecting the most appropriate method of solution, even hardware and software with some justification. Most attempt to solve the problem whole, without breaking it into manageable chunks and solve the individually, then combine them into one solution later.

A substantial computer-based problem can only be solved by breaking it down into sub-problems. The background description of the system, expected outcomes, user interface requirements, security and hardware requirements are rarely linked, pointing to the lack of skills to make well-informed decisions.

Students are not able to explain their own reasoning; another skill in critical thinking. They should be able to explain why they select one type of solution over the others, why they intend to use some software and not the other, why a certain hardware type and not the other, choose certain designs of input forms, output reports, processing procedures over others, and why their choice is the most appropriate. If they are not doing that, then they are not thinking critically. Even testing strategy and the actual testing has to do with the choice of data to be used, be it normal, extreme and abnormal data.

Lastly, the students are not able to solve unknown problems. If the students have not encountered the problem before, they do not have a way of solving it. The teacher has to provide the answer, otherwise it remains unsolved. They cannot apply what has already been learnt to current problems. In computing problem-solving, students have to be able to make informed decisions, explain their own reasoning, and to solve unknown problems in the area of study.

This points to the (Facione 2013) report that a critical thinker is "habitually inquisitive, well-informed, trustful of reason, open-minded, flexible, fair minded in evaluation, honest in facing personal biases, prudent in making judgments, willing to reconsider, clear about issues, orderly in complex matters, diligent in seeking relevant information, reasonable in the selection of criteria, focused in inquiry, and persistent in seeking results which are as precise as the subject and the circumstances of inquiry permit." (p. 26). Most of these qualities of the

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critical thinker lack in our problem-solving project, thereby necessitating the need to inculcate these into out post-graduate students.

The authors propose some key questions that the students could ask during all the steps so that they do not get lost along the whole process. These key questions are summarised in Figure 3 for each step. They could be asked and reflected upon for students to develop the key critical thinking skills that are necessary for the project work

PROPOSED CRITICAL THINKING QUESTIONS FOR THE FIVE STEP PROCESS

We hereby present some questions that the students could ask during the development of their projects so that they are employ critical thinking in their work. These questions could be used so that the students are not distracted during the problem-solving project. We feel that the questions could significantly guide them to make well-informed decisions; to explain their own reasoning; and to find ways to solve unknown problems that are encountered during their work. *Figure 2* illustrates the suggested questions in the problem-solving steps.

Step 1: Problem Analysis

During problem analysis, the most important questions answered are:

a. What kind of problem is it?
b. Is it a software, hardware, database or telecommunication problem?
c. In what order are the processes carried out?
d. What data enters the system?
e. At what points in the system is the data entered?
f. Is the data verified and/or validated?
g. What types of files are used?
h. Which operations are carried out?

Students would benefit a lot by asking themselves these critical analysis questions to provide answers to the competences that they lack. This way they are able to suspend judgement while considering what exactly the problem could be.

The most common hardware problems are capacity and compatibility (Laudon & Laudon, 2002). One can tell that the computer capacity is exceeded by looking at response times. When a computer takes much longer to respond to a request than before; it usually has a capacity problem. It would be desirable to change the hardware components of the computer.

This change in hardware may also necessitate a change in software. Hardware upgrade therefore, may eventually require software re-writing. Also, compatibility issues have to be considered. Some software can only work with others. One has to ask if the new hardware will be compatible with the older ones and related equipment.

Software often presents problems because the existing software has to be replaced almost always. The most common software issues involve the creation of interfaces with existing software, database, management of cost and projects, and personnel. New software typically requires inputs from the old system. New interfaces have to be built for the new software; and this could be time consuming, expensive and a difficult process.

Step 2: Problem Understanding

Some of the questions that students could benefit from are:

a. Where does the problem come from?

b. Why is it still around?
c. What data is being kept?
d. How is data stored?
e. How is data processed?
f. Why it has not been solved before?
g. What problems arise in data collection, storage and processing?

Some fact or data gathering techniques have to be employed to find the answers to these questions. Personal interviews, questionnaires, and perusing written documents would provide the necessary data that can be useful for the understanding of the problem.

Step 3: Decision Making

In Step 3 some of the most crucial questions are:

a. What are the strengths/weaknesses of the current system?
b. What changes in technology (software and hardware) are required to solve the problem?
c. What solutions are possible for this type of problem?
d. What are strengths and weaknesses of alternative solutions?
e. What is the best solution among the alternatives?

These will help to make to make some decisions about what should and can be done. All alternative solutions have to be evaluated, stating the strengths and weaknesses of each individual solution. A solution that looks like it is weak at first could actually be the best for one type of organisation. Also the organisation's resources have to be taken into account.

Step 4: Solution Design

A solution has to be designed and planned, and if need be, modify one that already exists within an organisation. A logical design describes the general operational processes, the nature of input, output that the solution should require. The physical design involves more detailed specifications of equipment to be used, hardware, software, personnel, and networking requirements for the proposed solution.

Each one of the possible input/output devices and methods has to be considered, with their strengths and weaknesses. Depending on the decision made about the solution that has been selected, considerations of storage, processing, algorithms, and hardware and networking tools have to be evaluated. Therefore the following could be asked.

a. Which data is going to be collected together?
b. Which operational processes, are required for input, output
c. Which hardware (I/O, storage, processing, etc), software, personnel, and networking equipment are required?
d. What technology and procedures will make the system secure?
e. Which validation rules will be built into the application?
f. Which testing strategy is to be used and the results expected?

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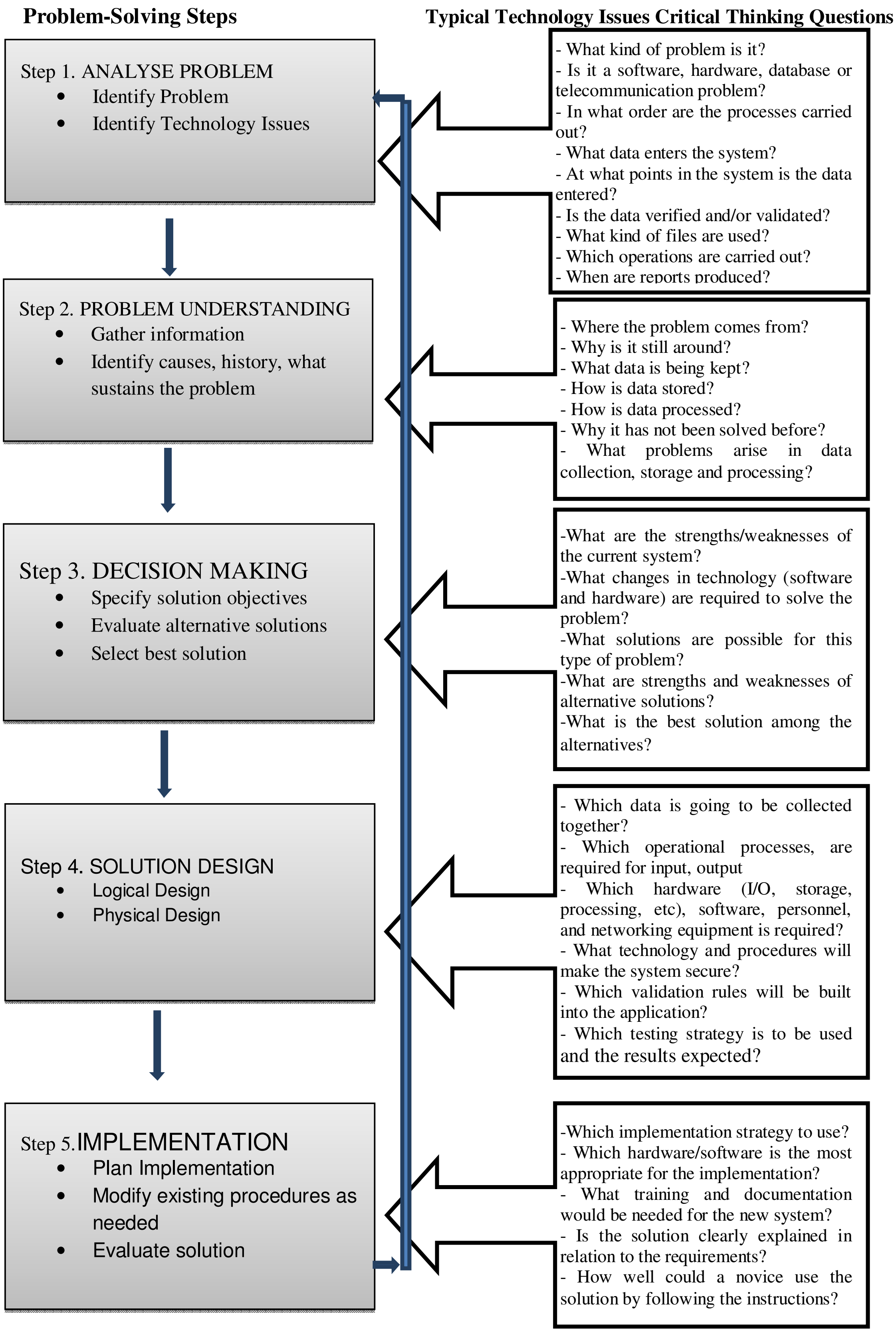

Figure 2. The Problem Solving Steps with Critical Thinking

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Step 5: Implementation

All solutions require a planned implementation strategy to work properly. Considerations have to be made as to when to introduce the solution, how to explain the solution to the stakeholders, how to modify the planned solution to account for field experience, how to change existing procedures so that the solution can work, and how to evaluate the solution so that it is working properly as required. Testing strategy has to be documented, and expected tests results have to be known before-hand so that the system does not surprise the developer of the system. The following questions would be of value.

a. Which implementation strategy to use?
b. Which hardware/software is the most appropriate for the implementation?
c. What training and documentation would be needed for the new system?
d. Is the solution clearly explained in relation to the requirements?
e. How well could a novice use the solution by following the instructions?

All these questions will guide and provide the necessary critical thinking skills that are required for the problem-solving at this level. There is need to ask and reflect on each question looking at the problem area one is working on. Project work is highly interconnected that a mistake in previous step would normally lead to a mistake on subsequent steps. There is therefore need to critically think of every step, and provide the most appropriate answer to the requirements at each of the steps.

LIMITATIONS

The main limitation of this study is that only the technological perspective of the major sources of business problems was considered. Technological problems are usually not the sole cause of an organisation's difficulties. Organisational and people perspectives also play a part. Technology solutions; though, are increasingly playing a larger role in the problem solutions. Secondly, document reading as a source of data also has a problem that data is restricted to what is written on the documents. Analysing documents requires substantial time and commitment, and it is not easy to come up with exact codes for the classification of the data. Also, our population comes from a homogeneous group, and the results cannot be generalised. The five-step process itself is rather rigid, and there are other alternatives that have not been considered in this work that have been used in other computing problem-solving as alternative methodological frameworks for the development of computer systems.

CONCLUSION

The results indicate that students are not employing critical thinking skills in project development. The goal for computing educators who want to instil critical thinking skills in their classrooms is to think of their students not as receivers of information, but as users of information. Learning environments like projects that actively engage students in the investigation of software and other tools, and the application of knowledge will promote students' critical thinking skills.

The greatest barrier to students' skill development is their perception that effective learning is characterized by the retention and recall of large amounts of information (Allen & Stroup 1998), and that correct information and answers are obtained from the instructors and textbook, and their task is to remember this information. Most students fail to recognise that critical thinking skills extend their abilities to understand information at a deeper level and can apply concepts to new situations. As with any skill, critical thinking requires training, practice, and patience. Students may initially resist instructional questioning techniques if

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they previously have been required only to remember in formation and not think about what they know. They may struggle with assessment questions that are not taken verbatim from the book. However, by encouraging students throughout the process and modelling critical thinking behaviours, students' critical thinking skills can improve. In the long-term, students can critically think for themselves and solve real-world problems.

It is not proposed in this paper that critical thinking is as easy as learning a number of questions and being able to apply them to a problem. Rather learning these questions in project development will help students to be aware of the need for critical thinking skills. It is our intention to implement this questioning technique with future students to measure its effectiveness on the development of critical thinking in computer education students.

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