

Programming in the real world

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Abstract

This article reports on a learning experience that was designed to investigate the extent to which a learning event would draw from both objectivist and constructivist traditions to provide learners with real-world projects so that they can construct their own programmes in collaboration with other individuals and develop new ideas for future systems. The study was done because the current South African curriculum for high school Computer Studies, in our opinion, is weak on higher order thinking skills. An experimental lesson was presented to high school learners, and monitored to determine the extent to which a learning experience could be designed using predominantly objectivist methods, but presented in a constructivist fashion. The evaluation showed that the lesson was successful. Learners scored better in their year-end results than previous years, and indicated that they enjoyed the real-world style. Using techniques developed for this lesson should help learners to do real world programming, and this would narrow the gap between school/university and the real world. Some recommendations for curriculum design emerge.

Key words: Computer programming; constructivism; curriculum design

Introduction

In an ongoing exploration of the relationship between objectivism and constructivism in curriculum and instructional design, a series of projects have been undertaken by students of Computer-Integrated Education at the University of Pretoria to explore the extent to which these two seemingly opposite educational

approaches can be integrated. In keeping with Herrington and Oliver's (2000) call for authentic learning tasks in instructional design, this paper reflects on an attempt at discovering to what extent constructivist outcomes can be reached by using traditional (objectivist) instructional design sequences, but using constructivist facilitation methods and tools. This article reports on such a learning event designed according to an essentially objectivist approach, following Gagne's events of instruction but executed in a constructivist fashion, as defined by Jonassen (1991). The overarching question driving the research is "In what way can objectivism and constructivism be integrated to create a single, meaningful and effective learning experience?"

Current South African educational policy calls for outcomes-based education that focuses on higher order thinking skills. However, an analysis reported by Brittz (2004) shows that the South African curriculum statement for higher grade Computer Studies in high schools does not reflect this. The Australian curriculum, for instance, provides more outcomes on the higher levels than the South African one. To address the discrepancy between policy and practice, it is necessary to show that South African learners are able to function in a constructivist learning environment, and reach higher levels of Bloom's (1956) taxonomy of the cognitive domain than is called for in the current curriculum statement. It is also necessary to develop teaching methods that would encourage learners to function at higher levels.

Muuren (2003) demonstrated that a learning event that drew from both axes had the advantage of being efficient from an objectivist perspective, as it tended to speed up the learning process. on the other hand the constructivist elements led to more effective, deep learning which resulted in better performance in authentic tasks.

The following sub-questions questions refine the main question stated in the first paragraph:

- How does the application of instructional design principles for designing learning events contribute in making learning efficient?
- In what way would constructivist learning stimulate higher order thinking?
- In what way does the role of the teacher change when authentic tasks are used?
- What new roles are required of the learners when authentic tasks are used?

This article takes the form of a narrative, in which we tell the story of the learning event we designed and the lessons we learnt. We make no claim about the transferability of our results, but present them here as an attempt to bridge the largely artificial gap between two equally important approaches to teaching and learning. The methods we used were participant observation by the two teachers on the project, analysis of learners' test scores, informal interviews with participating learners, and a survey questionnaire returned by them all. We discuss some of the principles that guided our thinking in the design of the learning event, then describe the learning event that was designed and discuss what we learnt in the process.

Theoretical underpinning

In order to answer the main question and its sub-questions, we consider the perspectives of objectivism and constructivism, as well as the possibility of integrating these two diverging epistemologies into teaching and learning. Upon this follows a discussion of classical objectivist instructional design, and a speculation as to its ability to accommodate constructivist learning with authentic tasks. Then we consider constructivist tools and methods, and finally investigate the changing roles of teachers and learners in an authentic learning environment.

The integration of objectivist and constructivist epistemologies

Policy statements on outcomes-based education in South Africa, such as the Department of Education's national statement for Computer Studies (South Africa, 2002), call for a move away from "old" objectivist approaches towards "new" constructivist methods. Table 1 provides a synthesis of policy documents, emphasizing this division.

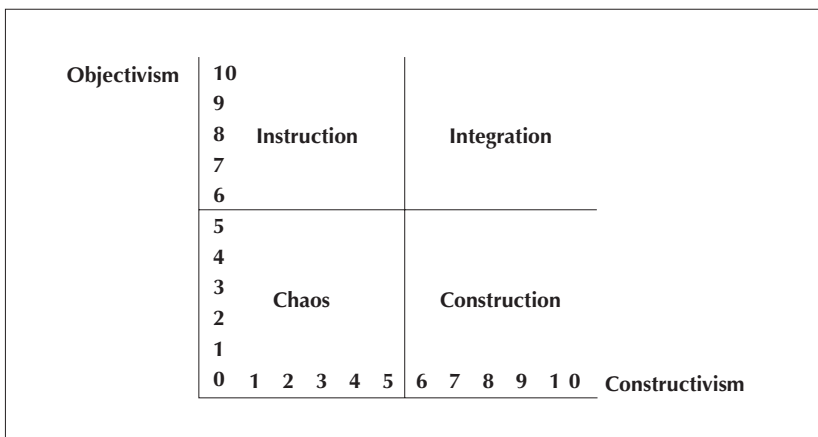
Table1: *Shift in government focus (South Africa, 2002)*

Old	New
<ul style="list-style-type: none"> • Passive learners 	<ul style="list-style-type: none"> • Active learners
<ul style="list-style-type: none"> • Exam-driven 	<ul style="list-style-type: none"> • Learners are assessed on an on-going basis
<ul style="list-style-type: none"> • Rote-learning 	<ul style="list-style-type: none"> • Critical thinking, reasoning, reflection and action

<ul style="list-style-type: none"> • Syllabus is content-based and broken down into subjects 	<ul style="list-style-type: none"> • An integration of knowledge; learning relevant and connected to real-life situations
<ul style="list-style-type: none"> • Sees syllabus as rigid and non-negotiable 	<ul style="list-style-type: none"> • Learning programmes seen as guides that allow teachers to be innovative and creative in designing programmes
<ul style="list-style-type: none"> • Emphasis on what the teacher hopes to achieve 	<ul style="list-style-type: none"> • Emphasis on outcomes – what learner becomes and understands
<ul style="list-style-type: none"> • Behavioural approach to learning and assessment 	<ul style="list-style-type: none"> • Cognitive approach to learning and assessment
<ul style="list-style-type: none"> • Assessment of isolated knowledge or discrete skills 	<ul style="list-style-type: none"> • Knowledge, abilities, thinking processes, meta-cognition and affect assessed.
<ul style="list-style-type: none"> • Individual learning and products 	<ul style="list-style-type: none"> • Collaborative learning and products

One of the problems associated with the rejection of an objectivist epistemology as “old”, and therefore undesirable, is that valuable educational moments may be lost. Cronje (2000) suggests a model whereby the two approaches are not seen as linear opposites, but are plotted as complementary approaches at right angles, thus creating four quadrants of learning.

Figure 1: *Four quadrants of teaching and learning (Cronjé, 2000)*



In figure 1, the Instruction quadrant contains essentially objectivist elements such as formal lessons, exercises and drills. The Construction quadrant is the domain of problem-based learning. In the Chaos quadrant serendipitous, trial-and-error learning takes place. The Integration quadrant is the one in which an educator or instructional designer uses a blended approach containing purposefully selected elements from both dimensions, based on pre-determined teaching objectives and desired learning outcomes.

Designing instruction

In keeping with our aim of creating a learning event that is high in both instructivist and constructivist elements, we adhered closely to the classical instructivist/objectivist approach espoused by Gagne's events of instruction. (Gagné, Wager & Rojas, 1991), viz:

- *gaining attention*
- *informing learner of lesson objectives (Outcomes)*
- *stimulating recall of prior learning*
- *presenting stimuli with distinguishing features*
- *guiding learning*
- *eliciting performance*
- *providing informative feedback*
- *assessing performance*
- *enhancing retention and transfer*

It is clear that these events of instruction are designed specifically to ensure efficiency in learning. They are aimed at creating focus on one specific aspect and ensuring that it is mastered. It is generally recognised that Gagne's work follows a predominantly objectivist epistemology, as can be seen if one were to compare the events of instruction listed above to the categories and explanations of objectivism in table 2.

Table 2: *Objectivist assumptions (Compiled from Cobb 1994, Jonassen 1991, Philips 1995, Lakoff 1987, Vrasidas 2000)*

Category	Assumption
The real world... their	has entities that can be categorized on the basis of properties and relations.
Reality ...	is fully and explicitly structured in a way that is shared by all who perceive it. Because of this commonality, reality can be modelled and shared with others.
Symbols ...	are representations of reality, and are only meaningful to the degree that they correspond to reality.
The human mind...	processes abstract symbols and fashions them so that they mirror nature.
Human thought ...	is symbol-manipulation and is independent of the human organism..
Meaning...	exists objectively and independently of the human mind and is external to the knower.

According to Savery and Duffy (1995), all learning activities should be attached to a larger task or problem. The design of the task and learning environment should reflect the complexity of the real world and should at the same time challenge the learner's thinking. Learners should be encouraged to test their ideas against alternative views. The opportunity to reflect on learned content and the learning process should be supported. Herrington and Oliver's (2000:25) synthesis of the literature shows that situated learning environments: "

1. Provide *authentic contexts* that reflect the way the knowledge will be used in real life
2. Provide *authentic activities*
3. Provide access to *expert performances* and the modelling of processes
4. Provide *multiple roles and perspectives*
5. Support *collaborative construction of knowledge*
6. Promote *reflection* to enable abstractions to be formed
7. Promote *articulation* to enable tacit knowledge to be made explicit
8. Provide *coaching* and *scaffolding* by the teacher at critical times
9. Provide for *authentic assessment* of learning within the tasks."

At face value there seems no reason why these constructivist activities cannot be included in a learning event designed using Gagne's events of instruction.

Constructivist learning

While the design of the learning event for the purposes of this study was essentially objectivist, the way in which it was presented took careful note of Jonassen's (1991) challenge to the instructional design community to be more constructivist in their approach. Table 3 shows the elements of constructivism that underpinned the practical presentation of the learning event.

Table 3: *Constructivist assumptions (Compiled from Cobb 1994, Jonassen 1991, Philips 1995, Lakoff 1987, Vrasidas 2000)*

Category	Assumptions
The real world...	is structured by our individual minds on the basis of our interactions (this limits what we can know about the real world).
Reality ...	is local (personal) to ourselves in a universe of multiple realities. Our realities are modelled by the way in which we personally construct them.
Symbols ...	are products of culture that are used to construct reality.
The human mind...	perceives and interprets the world by creating symbols.
Human thought ...	is imaginative, and develops out of perception, sensory experiences, and social interaction.
Meaning...	is a construction that is the end result of an interpretive process that depends on the experience and understanding of the knower.

The key aspect of a constructivist learning experience that forms the basis of this research is that learning should focus on the real world. In addition to this we added the concept of collaboration.

For De Villiers (2002), "Collaborative learning can be implemented in various ways, but [it] usually refers to groups of learners working jointly on a project, with the intention of producing a joint product". For Savery and Duffy (1995),

the value of individual understanding can be evaluated when learners share and debate perceptions and interpretations. Everybody has individual skills, which applied in group-work will give each learner a broader perspective of the final product. Group work plays a major role in constructivism (Lebow, 1993). In South Africa, learners were used to doing everything on their own, seldom if ever working in groups. In the past couple of years, educators in the South African outcomes-based education system have increased the use of cooperative learning methods in their teaching.

Constructivist methods

A number of teaching and learning activities identified from the literature as being more suitable in a constructivist learning environment include play, exploration, experimentation, conceptualisation and brainstorming. As it builds upon fantasy (Malone, 1981), **play** stimulates creativity on levels that are not easily accessible with normal teaching methods (Baum, 1990). Play is a method in which students can create new games, graphics and ideas by playing along. They begin to create new and better ideas by analysing other games and evaluating the programme segments. **Exploration** and **experimentation** allow learners to examine, read, touch and try out every aspect of the model or content with which they are busy. Based on curiosity (Malone, 1981) they encourage learners to compile and organize new mental models. By exploring new content, learners create new meaning and structure in the content (Crump, Schlichter & Palk, 1998). Reconstructing, rewriting, reorganizing and rearranging are the principles of experimentation (Hudgins & Edelman, 1986). Ideas start getting a new meaning when they are **conceptualised** (Sternberg & Bhana, 1986). Drawing a storyboard, picture, flowchart or a concept map focus the mind on another part of the brain. Processing the idea and picture stimulates the brain into new meanings and structures. **Brainstorming** creates new thinking patterns to help learners to see things in a different light.

Construction tools

Mindtools such as matrix analysis and key words have been identified as useful tools to use when applying constructivist methods. For Jonassen (1996:iv), "A Mindtool is a way of using a computer application programme to engage learners

in constructive, high-order, critical thinking about the subjects they are studying". Jonassen (1996) compares the way in which students learn and construct meaning to a carpenter. While the latter uses tools to manufacture a chair or table, so a student uses intellectual tools to construct knowledge. In a matrix analysis features and attributes of a model are identified and used as column headings. These attributes can be dimensions, colours, weight, style, skills, etc. Underneath each heading all the variations of that attribute should be listed. By mixing the variations differently, new models can be created. Key words allow for a common understanding of what is required during a constructivist learning task. Table 4 shows the key words that could assist the teacher in planning the learning event (Bosch, 2001).

Table 4: *Key words that will assist the teacher to plan the event (Bosch, 2001)*

Key words	Definition
Substitutions	Generates new ideas by substituting words and ideas with better ones
Combinations	Combining words and ideas help to create new ones
Adapting	Adapting ideas to incorporate new ideas
Modify	Modifications must be made to plans so that new ideas can be viewed in action
Magnify	Generate magnifications of words and ideas
Minify	Generate "minifications" of words and ideas
Put to use	Put certain words to other uses
Eliminate	Eliminate unnecessary words
Reverse	Make reversals to key phrases
Rearrange	Rearrange the words and sentences into new meanings
Fluency	List as many ideas possible
Flexibility	Approach the problem in a number of different ways
Originality	Generate as many as possible clever, unique or unusual ideas
Elaboration	Expand and develop as many ideas as possible by adding details and making changes
Curiosity	Seek additional information and carry out independent study
Risk-taking	Be willing to change, to defend ideas, to experiment, to predict and to put plans into action

Complexity	Seek alternatives, deal with intricate problems and ideas, and develop plans into a logical order
Imagination	Visualize and imagine plans, thoughts, ideas, outcomes and consequences to a high degree

The changing roles of the teacher and learner

Although it is agreed that the role of the teacher shifts to that of facilitator, and although clichés such as the teacher becoming the *guide on the side* abound, very little is said about what the teacher-as-facilitator actually does. Similarly, although much is said about learners having to *take charge of their own learning*, very little is said about what that actually involves. The following section contains a number of suggestions gleaned from the literature.

Cooperative learning allows learners to learn from one another, thus freeing the teacher to act as a high-level consultant. Johnson and Johnson (1991) identify a common purpose, mutual interdependence and individual responsibility, as three key concepts to ensure successful cooperative learning. The perspectives and views of others enrich each learner (Singhanayok & Hooper, 1998).

Presentations by students help them and their teachers share responsibility for the new content. The world we live in is very competitive. When students have to prepare new content and present it the class, they want to impress their teacher and their classmates. This should create a desire in a student to present a better model than the teacher and his or her classmates. They will compare, discriminate, criticize and generate as many new ideas as possible. This process stimulates the students' minds into new creative and better structures and models (MCREL, 1985).

When students are asked to **design** and **produce** their own models they are forced to use more and higher-level thinking skills. While designing and producing new models, they analyse, synthesize and evaluate new ideas to form their own model (Robinson, 1987). Papert (1993) refers to this approach as constructionism.

Problem solving helps students to construct new ideas. If they are asked to solve a problem in any situation, their thinking begins to work in a new way. One's mind is challenged to find the best solution for oneself and for one's group. In this situation, the teacher plays the role of a facilitator and is no longer the instructor. The teacher can play the role of a user in the real world, and can also be the project leader who directs learners in the right direction and for the remainder of the journey is regarded simply as another source of information. Words, construction of sentences and rephrasing of sentences can help the learner to understand the problem better. The teacher should make sure that the learner reads through the whole problem so as to get a global idea of it (Jonassen, 1991). The learner should explain the problem to other learners and they should explain their problems to him or her. This will help to reflect what is and is not important to each learner. The learners should then study different aspects of the problem to see if they can rephrase the problem and put it in their own words. The last step for the learners is to see how many solutions they can arrive at by using all the resources available to them. These solutions will help them with the next step, and will prepare their minds to think in a new way. One should bear in mind that the learner is part of the solution.

Learners should develop strategies or plans that will lead to a solution. The teacher should first introduce a few strategies, after which each learner should decide his or her own plan. De Bono's, (2002) strategies for lateral thinking were found to be very useful in the planning stages of the project.

Pogrow (2000) suggests that learners could learn from their mistakes and from one another. They should use other learners' knowledge and capabilities to help them to execute their plans, so helping them to see the plan from different perspectives. If their planning has been done correctly, implementation will go smoothly. On the other hand, if certain procedures are missing from the planning, the learner should go back to the original plan and adapt his or her plans accordingly.

Evaluation is the highest level of Bloom's (1956) taxonomy. Learners determine if the solution is the best one for the problem. If not, they should start the process all over again. Here the teacher and other learners play an important role. They can help one another to focus on words, strategies and problems which the learner has never seen before. Throughout the process learners should be

encouraged to engage in thinking about their own thinking (metacognition). Stimulating the learners with key words will set their thoughts on a new tack (Bosch, 2001).

Assessment and evaluation

Bloom's (1956) *Taxonomy of Educational Objectives* identifies six major types of learning, ordered from lowest to highest. While the authors are familiar with Anderson and Sosniak's (1994) improved version, we have chosen to retain the original as it is attuned more specifically to the objectivist tradition, and more generally accepted codebooks and ontologies exist for describing each taxon.

Willis and Wright (2000) suggest various alternative forms of constructivist assessment, such as projects, portfolios, activity logs, and the keeping of journals. Jonassen (1991) proposes criteria for constructivist evaluation. The tasks should be original and should cover multiple perspectives. The evaluation should be context-driven and goal-free evaluation methodologies should be used. Collaborative, negotiated construction should be of multi-modality.

Project description

In order to explore the possibility of adding a real-world context to a computer studies lesson a problem was introduced to 28 Grade 10 Computer Studies learners (with an average age of 16) at a high school in a relatively wealthy area of Pretoria, South Africa. Every year the school raises funds by selling flower bulbs to the community, an activity that takes many hours to administer. Learners were asked to computerize the whole process and create a system that could be used each year and be maintained for the next five years. The teacher responsible for the fundraising-project approached the Computer Science department on several occasions to ask for a programme that would be able to do what was required each year. This formed the basis of the constructivist learning event. The objectives of a real world context and collaborative work could be incorporated. Students could be put into project teams in which they could take the roles of project leaders and systems analysts.

The learners therefore had to develop their own project in a real life context and in collaboration with other learners. The flower bulb teacher was the end-user

and the Computer-Science teacher was the project manager. The principles gathered from the literature were followed in allowing learners to create their own ideas, work cooperatively and share the responsibility for the success of the project. The teacher, acting as project manager, would ensure that the learners read through the whole problem, and approached the task systematically.

The learning event

The learning event will be described according to Gagné's nine events of instruction, while we will indicate how the design principles mentioned above were incorporated.

Gaining attention

The learners were told about the flower bulb project. It was explained to them that someone had to write the project and they were asked whether they as a class would be interested in writing this project. Everyone agreed to do so.

Informing learner of lesson objectives

There were two sets of objectives. Firstly learners were expected to understand and implement the following aspects of a programming project:

- the life cycle of a project
- communication with end-users
- keeping records of all documentation used and signing off the stages in the life cycle of the project
- project maintenance
- selection structures and loop structures
- debugging of a project using trace tables

In order to develop the above understanding and skills in a authentic constructivist setting, learners had to participate in a project. The objectives of the project were to:

- Create the menu for the project. Declare all variables, the frame of the main programme, and all the input to the project – this would be the task of group one.

- Generate a list of all pupils selling more than R200 of bulbs – this would be the task of group two.
- Generate daily totals with the pupil and grade selling the most – this would be the task of group three.
- Generate weekly totals for the pupil and grade selling the most – this would be the task of group four.
- Generate a final report on the top three pupils selling the most bulbs. Also generate a report on how the different grades have fared – this would be the task of group five.
- Be sure that input and output are user-friendly – anybody should be able to use the programme.

Stimulating recall of prior learning

The learners were reminded of a game they had to write as part of a learning task they had been given three months previously. The process of writing the game was explained and a recalling of the stages of writing it used to introduce the new project. Objectivist instruction was continued alongside the project, by way of classical lessons in various aspects of programming. This content then formed prior learning for phases of the project.

Presenting stimuli with distinguishing features

Because the teacher represented the user for which the programme was being written, he simulated real world conditions by meeting with the project leader and discussing everything that had to be done. The project manager asked all the questions that he needed to and noted everything down in writing. A fixed date for implementing the programme was agreed upon. The project manager had to provide the user with a budget, then hold a meeting with five learners playing the role of analysers with each one's sub-project being given to them. The analysers planned their projects and divided them into sections, followed by a meeting with learners acting as their programmers (3-4). Each one had to construct their section. The analysers monitored progress and help was given where necessary. The project manager monitored each analyser and had meetings to discuss problems and the progress of the project. In this way cooperative learning and shared responsibility were encouraged.

Each group had to do the following:

- Interview the end-user about the conditions and features of the project.
- Write about their part in the project in their own words.
- Draw a mind map of their part of the project.
- Present a blueprint with dates, deadlines, budgets and sign-offs to the end-user.

They then had to report back on everything that was done, as a way of reflection and metacognition.

Guiding learning

Learners were guided throughout the design and development phase of the project, encouraged to use their mind maps and to collaborate with team members to get the best plan on the table. The teacher project manager, who had experience of real life programming, could foresee certain problems in some areas and asked the learners concerned to re-design their work in those cases. Learners were also encouraged to use some of the key words (explained in the literature survey), with those such as *substitute*, *modify*, *put to use*, *eliminate*, *rearrange*, *curiosity* and *imagination* amongst the ones used.

Higher order thinking skills were fostered by the use of play, exploration, experimentation, conceptualisation and problem solving in the class. Learners were encouraged to use a search engine on the Internet to help them to solve some of their difficulties. They were also helped in areas where new programming was needed, and had not been done before.

Eliciting performance

Groups were informed of the time schedule and sign-off dates, with penalties exacted in the form of marks deducted when deadlines were not met. If, however, the group managed to finish and implement their work before the deadline, extra marks were allocated. These were also given for creativity, collaborative work, well-designed projects, error-free projects and new programming ideas.

Providing informative feedback

The end user teacher made comments on the usability and friendliness of the programme, because he was not one-hundred percent computer-literate. The design and programming feedback came from the teacher, always consisting of comments that helped learners to be more creative and to think other (novel) ways. They were also designed to assist in the metacognitive process.

Assessing performance

In keeping with constructivist methods the learners had the opportunity for self-assessment. They had to assess their own work as well as that of their group members. The system analysers gave each member a mark and the learners, together with the project manager teacher, assessed the system analysers. In cases where the project manager teacher noticed that learners were not working he made a note and it was reflected in their marks. The most important aspect of evaluation was their construction of ideas. Before the project started pupils were reminded that extra marks would be given for creative ideas.

Allocating these marks was not easy, but depended on what and how the teacher assessed a learning outcome. Some of the pupils argued that what the user thought was not exactly creative to *him* was very creative to *them*. Both sides argued their views and, in the end, a mark was given that would (it was believed) reflect the product in the real world (Willis & Wright, 2000).

Each learner had his or her own portfolio. All the researched materials, images, flowcharts, pictures and the black book were kept in the portfolio. The black book operates like a notepad. When any idea or new thought comes up, it is noted down immediately. Just as in the real world, specifications are written in a contract for the project. Any changes from the user's side were noted in the black book and were signed off. All dates and appointments were recorded in the black book, which was also assessed, together with the portfolio.

When the project had been completed, the analysers implemented the programme and, together with the project leader, assessed the whole project and submitted their results. The user (teacher) evaluated the project and gave his results, as well as his recommendations for future projects.

Enhancing retention and transfer

The project ran over a period of three months, during which time maintenance had to be done on it. This means that some of the aesthetics and programming had to change to make the project more streamlined and user-friendly for the end user. The groups had to backtrack to do this. The learners were asked to note in writing that aspects of the project that could be improved.

Summary

Brittz (2004) introduced a model aiming at higher order thinking skills. This model was used for the project (Table 5). The first column shows the steps taken to solve a problem, from the problem to maintaining the model built. The second column focuses on the key words used to plan each step. The third column identifies the role of the student during each phase. Column four refers to Bloom's taxonomy. Column five indicates the role of the teacher during each phase. The last column shows the assessment that is required in each phase.

Table 5: *Summary of learning even planning*

Building steps	Key words	Role of learner	Bloom's taxonomy	Role of educator	Assessment
Problem	Content	Study the relevant content.	Knowledge: defines, identifies, states, outlines, selects and reproduces	Present an introduction and all the information available that will assist students to understand the problem.	* Portfolio * Is problem statement according to plan?
	What do I have to know?	Write problem in your own words.			
	Why?	Write your own goal for this project.			
	Information	Gather all the relevant information so that you can understand the problem better.			

Building steps	Key words	Role of learner	Bloom's taxonomy	Role of educator	Assessment
Plan	Mind map	Draw mind map of whole project.	Comprehension: estimate, explain, extend, give examples, interpret, rewrite, summarize	Observe and give guidance where necessary.	* Portfolio * Will the model meet the goals that are set by the student? * Give a first mark for product.
	Blueprint	Create a blueprint of the steps that you will take to realise the project.			
	Model	Build model of final product.			
Design	Research	Gather all information that is needed to complete the project.	Application: apply, change, produce, use, modify, prepare, relate	Observe and assist with information.	Portfolio
	Design Write and	Write and draw all information into a model.			
	Little black book	Make notes of everything that happens in the whole process.			
Construct	Share	* Collaborate with other students. * Get another perspective.	Analysis: Compare, contrast, differentiate, relate, break down	Observe and provide alternative models to bring out the best in each student.	* Portfolio * Give a second mark for product.
	Build	* Create the model * Put all together			

Building steps	Key words	Role of learner	Bloom's taxonomy	Role of educator	Assessment
Re-thinking	Testing ↓ Problem/ errors ↓ Reconstruct	Test the final product for any problems. Let other students test your product. If problems occur, reconstruct and make adjustments.	Synthesis: Combine, compose, modify, reconstruct, reorganize, revise, rewrite	Actively participate and give input so that you get the best out of the student.	Portfolio
New ideas	New ideas ↓ Construct ↓ Add/delete	Do maintenance on your product and compare it to new products on the market. Construct new features for your product. Add/delete new ideas to/from your product.	Evaluation: Appraise, criticize, evaluate, compare, support	Give feedback and information about new products and new models.	* Portfolio * Give a second mark for product.

Discussion

The questions asked at the beginning of the chapter will be answered in this section, and will form the sub-headings. We will consider first the contribution of cooperative learning, then of the objectivist instructional design. Finally we shall discuss the changed role of the teacher and learner, and come to some conclusion about the integration of the two perspectives, objectivism and constructivism, in one learning event.

In what way would constructivist learning stimulate higher order thinking?

Herrington and Oliver's (2000) suggestions for authentic learning environments formed the constructivist basis for presenting our analysis of the narrative, discussed below:

Provide authentic contexts that reflect the way the knowledge will be used in real life

Interviews and observation showed that most of the learners enjoyed working with teachers as user and project manager. This made their efforts worthwhile. After they had held discussions with the teachers, they applied their knowledge so realistically that they were commended for their efforts, particularly by the teacher acting as the client, who remarked on the usefulness of the end product.

Provide authentic activities

Constructing can be fun, particularly when the end product will actually be used by a real user. Creativity was evident in the class. Ideas were shared, planning was done, based on feedback from the teacher who acted as the client, and contact was made with people in the real world.

Provide access to expert performances and the modelling of processes

Since the computer teacher had some previous commercial programming experience, he was able to act as an expert performer. This was also augmented by showing videos, which, of course, was an objectivist, rather than instructivist activity.

Provide multiple roles and perspectives

The learners quickly assessed their strengths and weaknesses and applied their skills where they were most valuable. Group one assessed their problem and Pierro immediately said he liked designing the menus. Justin immediately claimed the variables as his strong point. Adri gathered all the input – it wasn't her strong point but it was better than doing the menus or variables – her weak point. After two or three days, some of the learners changed from being analysers to

programmers. Gerard (group 4) decided to step down as analyst because that was not his strong point, and to focus instead on programming, which was.

Support collaborative construction of knowledge

Matrix analysis and brainstorming were used to finalize the project. The matrix was used to generate better ideas and brainstorming was used for the flow of the project and the screens outlay. Collaborative work played an important role because the groups shared the same variables. Group four had to wait for groups two and three before finalizing their part. Collaborative work played the key role in the construction phase. Getting different views of the structure helps the learner to process the material in such a way that a holistic view guarantees a well-formulated solution. The report of group five was wholly dependent on the programming done by groups three and four. Group five therefore held meetings with groups three and four each day and discussed the variables used, as well as the parameters.

Promote reflection to enable abstractions to be formed

Constructing can also be hard work. The project was scheduled for two weeks, but in the end lasted three. To ensure the best solution in the market, one needs to cost hard work and long hours. Collaborative work in groups stimulates higher order thinking skills. Viewing different aspects of the problem helps the students to achieve better results. Training the mind to process different views and assumptions polishes the higher order thinking skills of learners. Constructivism, including exploration and conceptualisation, and collaborative learning, constituted a workable learning experience.

Promote articulation to enable tacit knowledge to be made explicit

Most of the learners said in the survey that they enjoyed that part. Many new creative ideas were implemented. Bednar, Cunningham, Duffy and Perry (2002) suggest analysis of the content, analysis of the learners, and object-specific goals. These principles, together with a mind map, flow chart, blueprint and the little black book, helped learners to design the best possible model for a project. The use of the model presented in the lesson focussed the learners' attention on all the small design issues that sometimes get neglected. Mind maps helped learners

to develop each section as a stand-alone project. The flow chart helped learners to see the whole project at one glance. The blueprint helped them to administer the project, keep to dates and deadlines, and manage the financial side of the project. The little black book helped them to file all the changes to the project in one place.

Previously hidden creativity flowed from the learners as each member wrote his or her piece of the programme. They had to draw diagrams of what they intended to do. The flow of the project was presented in a large flowchart, which became the model used to build the project.

Putting all the single programmes together in one working system created some problems. Variables were not globally assigned. One analyser got the information wrong and used two different procedures. It took two days to solve that problem.

Provide coaching and scaffolding by the teacher at critical times

Our experience in the re-thinking phase has shown that testing a project for errors takes fifty percent of the total time allocated for the project. This was explained in the beginning, but in the real world, as the learners discovered, it can take much longer if the testing is not coordinated and if team members do not communicate effectively. The fact that learners had to learn by experience, and from their mistakes, meant that the project was delayed by one week. It was also necessary for the programming teacher, who acted as project manager, on occasion to resort to direct instruction, as well as asking guiding questions and giving other forms of scaffolding.

Provide for authentic assessment of learning within the tasks.

Learners used trace tables and the debugger from *Pascal* to test the programme. Groups tested one another's work and learners exchanged ideas to make certain sections better. The only section that needed reconstruction and re-thinking was the weekly totals. Although some errors occurred, they created an ideal opportunity to reflect on a real life situation and higher order thinking skills. Everyone worked together and brainstormed the problem until the best solution was used. Re-thinking helped with transfer of knowledge and this was indeed observed during this process. Finally, the product was implemented and evaluated.

How do instructional design principles contribute to making learning efficient?

Gaining attention

Being involved in a real-life project during which learners could participate in a regular school project by adding value to it served as the attention getter for this project.

Informing learner of lesson objectives (Outcomes)

If the learners don't understand the essence of the problem, they can't go any further. Writing the problem in their own words helps them to start generating new ideas. Writing their own goals helps them to set the pace and standard for the project. Nevertheless, it was necessary for the teacher to provide a clear set of instructions, and eventually to ensure that the learners understood them.

Stimulating recall of prior learning

In a real-world application such as this one, prior learning goes beyond just what was taught in previous classes. Learners also have to draw upon their interpersonal experiences, and their general knowledge of business and entrepreneurship. One of the problems was that, in many instances, learners lacked the prior learning to be able to conduct proper interviews with the teacher who acted as the client, to conduct planning meetings, and even to develop proper project management plans. It was thus necessary, in such times, to resort to direct instruction and even to showing students a video.

Presenting stimuli with distinguishing features

Video materials, interviews with the teachers, and even direct instruction, supplied such stimuli. Although these were more interventionist than we would have liked, and although it detracted from the authenticity of the task, it became necessary to avoid the project running even further over time.

Guiding learning

Writing the blueprint of the project required research. Each member in the group had a responsibility, which varied from interviewing the end-user to drawing the mind map. The learners had the theory to do the interview but didn't ask the questions to get to the essence of the project. Some guidance from the teacher was needed. The mind map was the real challenge, as learners first had to be taught how to draw mind maps, and then had to be instructed in some of the content that needed to go onto the maps.

The learners used the Internet to search for most of the information. They used *Google* as a search-engine, and key words like "flower bulb", "system cycle" and "ADDIE" (Analysis, Design, Development, Implementation, Evaluation) were searched, as well as links to existing projects. When observing the learners, it was interesting to see that most of them went beyond the links that were given to them. With some guidance, the groups produced excellent problem statements.

Eliciting performance

To generate the plan, the learners had to transfer the information gathered by the interviews into a working plan. This fostered high order thinking skills in that the learners analysed and then synthesised as they built the model. Although learners presented good blueprints, the lack of real world knowledge was noted at this point. Some of the learners (18%) did not produce the correct programme because they misinterpreted the instructions. One of the learners wrote: "Design means to code the problem in *Pascal*!" He did not understand the concept of planning at all. Higher order thinking skills played an important part in this construction phase. If the design is performed correctly, construction is easy. In some cases groups had to go back to the design and make changes. One group had to wait two days before they could continue. Building a structure from diverse elements is a high order thinking skill. For most students this was the most difficult part. Learners should be trained to build structures from different elements. In one instance one of the learners had great difficulty in programming a sorting procedure. Another learner gave him a nice idea but it took him much longer to construct the idea than time allowed.

None of the learners used the little black book to their advantage. If used correctly, it is a tool that manages all documentation and the extras that are added to the project. This tool is a must in the real world, and it would have required a stronger objectivist approach to force learners to use it.

Providing informative feedback

Some of the learners had all the knowledge and skills to write programmes, but found it difficult to apply this knowledge in a project in collaboration with other learners. One of the analysers (from group 4), one of the better programmers, had to divide the group's problem between three programmers. He had all the information but did not know how to apply it in the correct sequence of events. After some direct instruction and help from the project he could explain it to the other programmers in the group.

Assessing performance

For their final mark, groups had to maintain the project for three months. During this period, adjustments were made to the project to render the project more functional and more user-friendly. The learners did not understand this phase. When users use a programme in the real world they often complain about small things that do not work so effectively in the normal daily routine. This provided an opportunity to reconstruct and come up with better ideas. If one uses high order thinking skills, one can produce better programmes than other companies and this will give one's own company the edge that one seeks. After some explanation, learners understood this and made a few changes to the programme. Feedback was provided during the project and after everything was assessed it was discussed with the learners and reflected on.

Enhancing retention and transfer

Interviews and observations showed that learners could see many other applications for their new skills. Their final examination also showed an increase over their end of year results of the previous year, and over comparable results of the previous year's group.

To what extent does the role of the teacher change?

In our experience the most important change in the role of the teacher during this shift from being an instructor to being a facilitator, is that of project manager. While the learners were engaged in learning tasks the teacher was freed from the traditional task of lecturing, but had to provide a great deal of assistance, particularly in the field of project management.

It was also necessary for the teacher to model various real-life behaviours peculiar to programme developers – behaviours with which the learners were not familiar. A strange paradox arises here. Learners are given a “real world” problem – but the problem is not from *their* world. In our case a second teacher was used, playing another role – that of client. Here again the role was strained. The client would not pay for the end product, instead the project manager (computer teacher) would reward the learners with grades.

In the role of evaluator and assessor the teacher negotiated grades with the learners and formed part of a team of assessors that allowed for peer assessment.

What new roles are required of the learners?

The students enjoyed what they did in class. They worked for *themselves* and took pride in their work. They also had to work in teams with other learners, and take the roles of project managers, system analysts and programmers. The perspectives and views of others enriched each learner (Singhanayok & Hooper, 1998). The role of the learners has changed from that of passive listeners to that of active role players who construct and shape their own futures. Working together and collaborating with each other helped them to get closer to the real world tendency of group work in a project. They learnt to subject their own beliefs and ideas to others by focussing on the task and not on themselves. They learnt that two or three people could construct better ideas than one. They learnt to share their expertise and to speak in front of an audience (this improved their self-confidence). They learnt what the real world was all about. They learnt how to prepare a project, draw flowcharts, how to interview a user, what to look out for, how to use a little black book and make the user sign for any changes to the project.

The most important change for the learners was that they had to become assessors. This is a responsible role and learners need to be educated into this task. Learners didn't know how to evaluate. In evaluating other learners they gave each other high marks for work that had not been correctly done. Some did not even assess work but gave a mark of 86%. When confronted, they had some explaining to do.

The learners thought that the project was completed when it was implemented. After the evaluation process, they had to return to their planning to make adjustments. This took much longer than anticipated. Frequent evaluation gave the learners some peace of mind. If evaluation is done regularly, a student can rectify problems quickly and know that he or she is still on the right track. The portfolio brought the learner into contact with the real world. Everything should be kept in the form of a journal. Sign-off documents and changes are normally the big factors that distract the momentum of the project. Some changes to the project were made that were not documented. This caused a huge debate. From the student's point of view, they had to perform to satisfy *one* person's beliefs and thoughts. Now students evaluate and assess themselves. Individual skills as well as group work are assessed and together they work towards the ultimate goal – success. Constructing in the real world has changed the paradigm from getting good marks to constructing *for my own future*. They don't work anymore for their parents or for marks, but for themselves. They start building their own portfolio when constructing new models and projects. These portfolios will speak for themselves when they apply for a job.

Conclusions and recommendations

Generally the project was a success. It ran one week over time, yet what learners learnt was considerably in excess of what they would have done with conventional teaching, as is suggested by the improvement in their end-of year grade.

Interviews, observations and the questionnaire showed that the learners enjoyed the experience a great deal more than they would have a traditional class situation, and that this contributed to their learning.

Thus, in answer to our original question “To what extent can objectivism and constructivism be integrated to create a single, meaningful and effective learning

experience”, the answer is, the two can be integrated seamlessly, with the instructivist elements helping to speed up matters and to control the many variables that arise during a constructivist authentic exercises. Constructivist learning, on the other hand, allowed us to address higher levels of Bloom’s (1956) taxonomy, helped to create ownership and stimulated enthusiasm, while co-operative learning added a sense of responsibility.

It is recommended that, in order to accommodate learning events such as this one, the key words and content in the National Curriculum Statement need to be adjusted to address a greater number of higher-order thinking skills. Key words, such as *construct*, *design*, *illustrate*, *evaluate* and *interpret*, should set the scene for future curricula. Content should be in line with the projects students might work on and these should be relevant to the real world.

Projects should be done in a real world context. Everything that has to be learned in the computer classroom should be as real as possible. Projects, assessments and content should conform to real world conditions. Students should go out and interview programmers, system analysers and users to get the experience of the real thing. Players in the real world can help to assess projects.

Role players from the real world should be involved in constructing the outcomes for the new curriculum, and modelling behaviour during projects. These people can provide creative models and ways to attain the kind of outcomes that are needed in the real world.

Assessment should be according to performance in the real world. What are the key features of a successful project? These are the outcomes that need to be assessed. No longer can only one person do assessment. Inputs from the group are needed for the new way to assess work. While content can still be assessed individually, practical work should be done in collaboration with group members.

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